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THE STRUCTURAL UTILIZATION OF HARDWOODS IN THE ANDEAN PACT COUNTRIES: A REVIEW OF THE FORESTRY TECHNOLOGY PROJECT

by

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1. INTRODUCTION

The author was requested by the International Development Research Centre to review the progress of the Centre-supported Forestry Technology (Andean Pact) Project being carried out by the Junta del Acuerdo de Cartagena, with particular reference to Subprojects 3.2 (Grading), 3.3 (Structural Design) and 3.4 (Connections).

The specific terms of reference are as follows:

(a) to make a detailed evaluation of the research work carried out to date pertaining to timber design and engineering for use of tropical hardwoods in structural applications;

(b) to review the research undertaken to develop standards for grading tropical hardwoods and systems for assembling structural wood members;

(c) to assess and discuss the research methodology for the preparation of design tables and charts for a wide range of structures; and,

(d) to make recommendations on any action or changes which should be implemented in order to ascertain that the research being carried out will lead to the development of technology for the use of tropical woods for structural purposes in construction.

To this end, the author accompanied Mr. Gilles Lessard, the Associate Director (Forest Science) of the Agriculture, Food and Nutrition Sciences Division of the Centre, and Mr. Martin Chudnoff of the U.S. Forest Products Laboratory, Madison, Wisconsin, to Peru, Ecuador, Colombia and Venezuela in the period November 15 to December 5, 1975.

Within these four countries, the following were visited:

(a) offices of the Junta, Lima, Peru;

(b) field collection sites and sawmill, Bosque Nationale de Iparia, Peru;

(c) the wood technology laboratories, Universidad Agraria la Molina, Lima, Peru;

(d) Centro de Investigacion y Capacitacion Forestal, Conocoto, Ecuador;

(e) Facultad de Ingenieria de la Universidad Catolica, Quito, Ecuador;

(f) Laboratorio de Resistencia de Materiales de la Facultad de Ingenieria Civil de la Universidad Central, Quito, Ecuador;

(g) offices of INDERENA, Bogota, Colombia;

(h) Universidad Distrital de Bogota, Colombia;

(i) Universidad Nacional de Medellin, Colombia;

(j) Laboratorio Nacional de Productos Forestales, Ministerio de Agricultura y Cria, Universidad de los Andes, Merida, Venezuela;

(k) offices of FAO Project VEN 019, Caracas, Venezuela.

At this point, the author would like to acknowledge with gratitude the complete cooperation extended to him by all members of the Project, particularly by Ing. Jose Carlos Cano. Sr. Cano accompanied the Centre team throughout its three-week visit and, in addition to being a charming travelling companion, tirelessly translated between Spanish and English at each visit in order to overcome the author's linguistic ineptness.

2. AN OVERVIEW OF THE PROJECT

2.1 The Problem as Perceived by the Junta

The forestry resources of the Andean Pact countries are underutilized - in terms of the volume of wood harvested, or the uses to which the wood is put, or both.

In regard to harvesting, it is understood that, in many areas, only a small percentage of wood is cut for purposes other than fuelwood, and that this small percentage is destined mainly for the export market and for domestic use as furniture and as decorative panelling.

Although there is an historical precedent for the use of wood in major public buildings and in grander private residences, wood is currently regarded as "the poor man's building material" or, at best, a temporary building material. Consequently, where wood is used in construction, it appears without benefit of professional design and thus is generally not resistant to the effects of earthquakes, fire and deterioration by insects and decay fungi.

Compounding the problem are the shortages of engineers, architects and craftsmen trained in the proper use of tropical woods in construction, and of courses and training programs to counter this shortage.

Nor, by and large, has there appeared to be (prior to the Forestry Technology project) any strong desire on the part of the governments, the financial institutions or the forest products industry to support the development of engineered wood products in construction.

Ironically, the problem of an underutilized, abundant and renewable resource of construction materials exists side-by-side with an area plagued by chronic housing shortages.

2.2 General Approaches to Solving the Problem

The Junta's method of tackling the problem consists of the following.

(a) To sample the forest resources of Bolivia, Peru, Ecuador, Colombia and Venezuela to the extent of 20 species per country, in order to develop a database for 100 species, many of which have not previously been studied to any extent.

(b) To determine the basic properties and characteristics of these species:
   (i) specific gravity
   (ii) natural durability
   (iii) treatability
   (iv) drying behaviour: rate, shrinkage, fiber saturation point
   (v) mechanical properties
   (vi) workability or machining characteristics
   (vii) jointing ability
   (viii) occurrence of natural defects appearing in sawn lumber.

(c) To prepare a manual (the "Cartilla") for the proper use of these species in construction, including architectural and structural design and urban planning.

(d) To develop an infrastructure, centred on the Project researchers in each country and based on the distribution of the Cartilla, of professionals, craftsmen, educators and government decision-makers familiar with the proper use of wood in construction.

(e) To encourage, through liaison with educators and the forest products industry, courses and demonstration projects to teach and display how wood can be successfully used in construction. This activity will also be based on the Cartilla.

The personnel involved in this work are listed in Appendix A.

3. DETERMINATION OF THE STRENGTH PROPERTIES AND ALLOWABLE STRESSES FOR STRUCTURAL LUMBER

3.1 Proposed Methods of Testing and of Deriving Allowable Stresses

In general, the approach is to test small, clear, green specimens of wood according to the provisions of ASTM Standard D143, "Standard Method of Testing Small Clear Specimens of Timber", and then to derive allowable stresses from these results by procedures of ASTM Standard D245, "Standard Methods for Establishing Structural Grades and Related Allowable Properties for Visually Graded Lumber".

The specimen testing can be done using either the Primary or Secondary Methods of ASTM D143, the difference corresponding mainly to the use of a 2" x 2" or 1" x 1" cross-sectional area for the static bending and compression parallel to grain tests.

The derivation of allowable stresses from these results is of particular interest. To illustrate the procedure, the allowable stress in static bending for in-grade, full-size lumber members is calculated by the following steps:

(a) obtaining the mean modulus of rupture value for a population of small, clear, green static bending specimens according to D143,

(b) deducting 1.645 standard deviations from the mean value to arrive at a lower 5% exclusion limit value,

(c) multiplying by a reduction factor representing the effect of duration of load when comparing ten-year strengths with ten-minute strengths,

(d) multiplying by a factor greater than unity to represent the increase in strength obtained as wood dries below the fibre saturation point,

(e) multiplying by a reduction factor representing the effect of beam depth when comparing full-size members to test specimens,

(f) multiplying by a reduction factor (the "strength ratio") which represents the weakening effect of growth defects (e.g., knots, sloping grain) which are permitted in a particular grade, and

(g) multiplying by a factor representing the factor of safety.

It is proposed in this project that the strength ratio values in (f) be obtained by testing full-size pieces of lumber which contain growth defects, and to compare these results with those obtained using clear test specimens.

3.2 Comments

(a) During discussions with the Project researchers, one question kept recurring: "Should the static bending and compression parallel to grain test specimens have a 1" x 1" cross-section or a 2" x 2" cross-section?" In his report, Martin Chudnoff gives the opinion that "This option should be open to all laboratories. Some data are available, though, that suggest there should be a slight adjustment of values based on the 1-inch specimen for comparison with 2-inch material. Thus, small beam values might be decreased 5 to 8 percent for modulus of rupture....."

The author cannot disagree with this opinion, but a warning should be given to avoid placing any great importance on the numerical precision of the results obtained. As explained in (b) below, the appropriateness of deriving allowable stresses for in-grade structural lumber from the results of small clear specimens is questionable. Instead, it is recommended that the results be used only to allocate the species to various strength groups, perhaps "high", "medium", and "low" strength groups for want of a better designation. Allowable stresses for these groups can be tentatively assigned using the proposed procedures in order to get on with the job of using the lumber in structures, but these stresses should be adjusted as soon as possible by tests on full-size, graded, structural members.

(b) The traditional approach of deriving allowable stresses from tests on small, clear, green specimens is challenged by the work of Professor Borg Madsen of the University of British Columbia. (Because of the importance of this challenge to the structural utilization of wood, a copy of his summary paper is enclosed as Appendix B.) In this paper, he presents test data which lead him to question the following steps in the allowable stress derivation process:

(i) the determination of the lower 5% exclusion limit value based on an assumed Gaussian distribution of strength values; this appears to be the case for small clear specimens but may not be for populations of in-grade lumber,

(ii) the effect of duration of load at the lower 5% exclusion limit,

(iii) the effect of moisture content changes at the lower 5% exclusion value,

(iv) the reliability of grading rules in predicting strength at the lower 5% exclusion limit.

Madsen proposes instead the proof-testing of in-grade full-size lumber, as described in the paper. As mentioned above, the author recommends this method of obtaining allowable stresses eventually, i.e., after the immediate project program of work is completed.

(c) ASTM Standard D143 includes several strength tests: static bending, compression parallel to grain, compression perpendicular to grain, tension parallel to grain, tension perpendicular to grain, cleavage, toughness, impact bending, nail withdrawal, hardness, and shear parallel to grain. It is the author's opinion that only two of these - static bending and compression parallel to grain - are particularly significant in the design process. The others lack direct applicability; for example, the size effects in shear parallel to the grain and in tension (and possibly, compression) perpendicular to the grain tend to overshadow the variation of these properties among the various species. Another example is the lack of direct relevance of the cleavage, hardness, nail withdrawal, toughness and impact bending tests to the majority of design situations. (In the latter two cases, a more appropriate measure of energy absorption during seismic loading is simply the area under the load vs. deflection curves of the static bending and compression parallel to grain tests.)

The author is nevertheless not prepared to recommend discontinuing these other tests because to do so could interrupt the momentum of the current testing program. It is mentioned here in order to assist in assigning priorities to the testing work in the event of financial, time or resource pressures during the project.

4. GRADING OF CONSTRUCTION LUMBER

4.1 Sawmill Survey

Because of the great variability in the quality of lumber as it comes from the sawmill, there is a need for some system of classifying or "grading" wood to reflect its relative freedom from those defects, like knots, which will affect its end use. Although the usual methods of grading hardwood lumber and softwood lumber are both related to the presence of knots (among other things), the approaches are different: hardwood grades are based on the amount of cuttings clear of knots which are obtainable from a board, but softwood stress grades depend upon the weakening effects of knots of certain sizes and locations in the plank. Consequently, it appears that the hardwood lumber studied in this Project will have to be graded using rules similar to those for softwood lumber.

The Junta has taken the very sensible approach of declining to automatically accept the North American grading rules (e.g., those of the National Lumber Grades Authority); instead, they have decided to go to the sawmill and record the types, sizes, locations, and species-dependency of defects in hardwood lumber cut in the Andean Pact countries. From this knowledge, a set of grading rules related to relative frequency of defect occurrence can be devised. Once this is done, one can then determine the "strength ratio" factors referred to in the previous chapter to be used in the derivation of allowable stresses; the strength ratios would be determined for the most severe defect permitted in each grade.

4.2 Comments

(a) The author agrees with the approach taken by the Junta in their decision to record defects contained in material coming from the saw and to relate their strength classifications to this. However, encouragement should be given to expanding and extending this program over the near future, because it is quite likely that defect-frequency occurrences will change with time. For example, it is possible that sawing techniques may change due to the essentially different end uses of the lumber being produced, with defects in the log being regarded differently by the sawyer for structural lumber than they are for furniture lumber. It is also possible that log characteristics will show greater variability as the exploited forest resource is expanded over the next decade.

Also for the future is the recommendation of the previous chapter that allowable stresses be based on proof-loading populations of in-grade lumber. This process is possibly best carried out at the sawmill; consequently, it is recommended that defect surveys a few years from now be combined with the proof-loading program, and that the process of defining strength grades and establishing allowable stresses be a continuing one.

(b) The next comment in regard to grading is a plea for simplicity. Recent work in Canada (discussed in Madsen's paper) indicates that our current grading rules are not dependably efficient in strength-ranking of the various grades at the 5% exclusion limit, and there is a school of thought favouring a consolidation and simplification of our stress grades. This includes both the number of grades and the board characteristics which define the grades. Martin Chudnoff, in his report, has made reference to the "H Super Group" used for hardwood lumber in parts of Africa as a reference to consider when developing grading rules and the author concurs, although it is possible that it is perhaps too simplified for the Junta's purposes. Another reference is the Guyana Grading Rules for Hardwood Timber which, while worth considering, is possibly more complex than is warranted in the present case.

(c) Considering the classification of lumber for construction purposes in the broadest sense, it becomes apparent that grading for strength properties is only one aspect. It may be equally (or even more) worthwhile to consider a classification based on overall suitability for various end-uses. In this respect, durability assumes major importance - durability against fungal decay and against insect attack - as well as the alternative consideration of its treatability with preservatives.

If this line of reasoning is pursued, there are several different formats for an overall classification system which might be worth examining. (It should be emphasized that all of this discussion assumes that the species of each piece of lumber is known or can be determined - this is an enormous problem in itself, but individual species determination is an objective of the Project, so let us proceed using this assumption.) One such format is the following. Two large charts are prepared: (i) a Service Requirements Chart, and (ii) a Species Properties Chart. The Service Requirements Chart shows, along one axis, the various specific construction elements for which wood can be used, e.g., finish flooring, subfloor, floor joists, load-bearing studs, non-load-bearing studs, columns, beams, exterior wall cladding, interior wall cladding, roof rafters, roof decking, roof trusses, foundation piles, structural poles, stairs and steps, finish woodwork, window frames, etc. Along the other axis of this chart are the minimum properties which a species of wood will have to possess to provide satisfactory performance, e.g., strength, stiffness, durability, treatability, workability, dimensional stability, fastenability, toxicity, thermal insulation, etc. It would also be reasonable to subdivide the minimum required properties according to the climatic zone in which these elements are to be used, e.g., coastal, mountain, forest. The classifications in the matrix might consist of "high", "medium" and "low".

The second chart, the Species Properties Chart, would then list, for all of the species considered, their rating for each of the properties listed in the previous chart.

Using these two charts, the material selection process in design reduces to the designer selecting the minimum properties he needs for the wood components of his structure according to the first chart, and then, from the second chart, determining what species will perform satisfactorily. This process has the additional advantage of being very flexible: the designer has essentially a free choice among a number of suitable species for any particular structural element and he is then able to impose the criteria of cost, availability, appearance, etc., to make his final species selections.

(d) In regard to the allocation of work on the Grading Subproject between the Junta and the national counterparts, it seems clear that the role of the counterparts should be restricted to the collection of data on lumber characteristics and that the process of grade development should be solely the responsibility of the Junta. To do otherwise would undoubtedly result in a diversity of philosophies which would substantially retard this effort.

There have been some comments that the data collection forms are not as well designed as they might be. Because of the crucial nature of proper communication on this matter, it is recommended that, where ambiguities may develop, Junta personnel should travel to the counterpart to clear up any difficulties as soon as possible.

(e) Another system of stress grading that was discussed was "machine stress rating". In this process, a small load is applied to a piece of lumber and the resulting deflection is measured, or vice versa. This enables one to compute the modulus of elasticity of the piece, and by means of a correlation between modulus of elasticity and modulus of rupture, the bending strength of the piece can be estimated. By applying a factor of safety, the correct allowable stress for that particular piece of lumber can be determined and stamped on the board. It is the author's opinion that consideration of this system of grading is premature. One reason is that there are actually only a few applications in timber construction where stress rated lumber is really needed, e.g., for fabricators of long-span light trusses and for laminating stock in glued-laminated timber. Another problem concerns the efficiency of the stiffness-strength correlation for in-grade lumber: this has been questioned. Finally, size standardizations for lumber are needed in order for a stress-rating machine to operate in a production situation. The last of these three reasons for deferring consideration of machine stress-rating is the least serious, but it underlines the fact that this system of grading is something for the future (if at all) and not for the present.

(f) Another consideration for the future is the hope that regional standards associations will develop out of the Junta's efforts, and that these will be responsible for the establishment and monitoring of grades and standard sizes for all wood products.

5. CONNECTIONS FOR CONSTRUCTION LUMBER

5.1 Proposed Methods of Test

This Subproject is concerned with testing the ability of the subject species to resist double-shear loads applied to nailed and bolted connections. To a large extent, the test methods are based on the requirements of ASTM Standard D1761, "Standard Methods of Testing Metal Fasteners in Wood". Two lengths of nail (2-1/2" and 4") and three lengths of 1/2" diameter bolt (3", 5", 9") are being tested for each of the 20 species selected by each country.

The nails are to be tested in species with a specific gravity not exceeding 0.6, and the bolts in species with a specific gravity greater than 0.6. All tests are to be conducted in the green condition. The experimental design is as follows:

(a) Specific Gravity $\leqslant$ 0.6

No. of trees per species = 10
No. of types of test per tree = 2
(i) 2-1/2" nails
(ii) 4" nails
No. of replications per type = 2
∴ 40 test specimens per species

(b) Specific Gravity > 0.6

No. of trees per species = 10
No. of types of test per tree = 6
(i) 3" bolt - parallel to grain
(ii) 3" bolt - perpendicular to grain
(iii) 5" bolt - parallel to grain
(iv) 5" bolt - perpendicular to grain
(v) 9" bolt - parallel to grain
(vi) 9" bolt - perpendicular to grain
No. of replications per type = 2
∴ 120 test specimens per species

The test specimens are all of the three-member type in which a double-shear force on the fasteners is produced. The nailed test specimen involves parallel-to-grain loading only; four nails are driven from one side. The compressive load is applied to the top surface of the middle member and the specimen is supported on the bottom faces of the two outer members.

The bolted test specimens are of two types - parallel to grain loading and perpendicular to grain loading on the middle member. The first type is similar to the specimen for nails in which all three members are aligned with their grain direction parallel to the load and compressive load is applied to the middle member. A single bolt is used in the test specimen. In the second type of specimen, the compressive force is applied to the outer two members which are parallel to the load. The middle member is perpendicular to the direction of load application, i.e., horizontal, and is supported on its underside.

5.2 Comments

(a) Each Laboratory should have the most recent edition of the ASTM Book of Standards on Wood Testing (Volume 22 of the 1975 Standards). It would appear that the most efficient way of accomplishing this is for IDRC to purchase the publications and to mail them to the various Laboratories; it seems that only the Merida Laboratory now has a copy.

O.K.

(b) Discussions about this Subproject revealed considerable uncertainty about the details of the test procedure to be followed. Because the interpretation and comparison of test results for this work crucially depend upon standardized test methods, it is strongly recommended that the general coordinator of this Subproject, Sr. Julio Cesar Centeno of the Merida Laboratory in Venezuela, prepare a very detailed test procedure, accompanied by a commentary, for distribution to the other countries for their comments and approval*, and then, if necessary, travel to the other countries to clear up any difficulties and to observe the tests in progress to ensure that the test procedures have not been misunderstood. Alternatively, individual researchers who wish discussions on this could come to the Merida Laboratory to watch tests in progress.

(c) Among other things, the following aspects of the test procedure should be prescribed:

(i) types of nails and bolts. It goes without saying that it is desirable to use the identical nail and the identical bolt in each country. However, there is certainly no single type of nail (and possibly no bolt) which is locally available in all of the Andean Pact countries. Because the test results must be usable in each country, it unfortunately appears necessary to deviate from the principle of fastener uniformity. In this circumstance, the author recommends that a preliminary survey of locally available nails and bolts be made so that those finally selected for test will be as similar as possible in regard to the following characteristics: diameter, yield strength, coating, shank surface characteristics, tip and head (in order of priority). These properties should be carefully determined and recorded in each country.

(ii) rate of loading. Although the difference is subtle, it appears that duration of test may be a more important test parameter than rate of loading. It is therefore recommended that any prescribed rate

*It would be appreciated if the author could receive a copy of this document.

of loading be regarded only as a preliminary guideline and that a desired test duration of between five and twenty minutes be the important prescription.

(iii) minimization of friction at the interfaces between the three members. The author recommends that steps be taken to attempt to eliminate the effect of friction in both the nailed joints and the bolted joints. One possible (but so far untested) method to consider is placing two sheets of wax paper in each interface. Another method which was proposed, and which the author does not recommend, is the placing of small shims between the members of the test joint. Objections to this include doubts about the uniformity and dependability of the shims being used properly, a problem which should not arise with the wax paper.

(iv) method of support of the bolted specimen with perpendicular to grain loading. It is recommended that the provisions of ASTM Standard D1761 be followed for this specimen, i.e., that the horizontal member be supported, not throughout its length, but on supports a clear distance apart equal to three times the depth of the horizontal member.

(v) fastener holes. The author recommends that nail holes not be prebored and that bolt holes be drilled 1/16" oversize.

(vi) bolt tightness. The recommendations of ASTM D1761 should be followed, i.e., "Abutting faces of joint members shall be brought into normally installed contact; the nut shall then be backed off and retightened to 'finger tightness'."

(vii) washer type and size for the bolted joints.

(viii) standards for workmanship. The criteria for "tolerable error" in regard to specimen fabrication (including squareness) and load measurement should be quantified and emphasized.

(ix) loading head. A spherical seat should be used.

(x) frequency of calibration of the testing machine.

(xi) sequence, timing and priority of tests. It is recommended, for bolted joints, that parallel to grain tests receive a higher priority than perpendicular to grain tests, and that bolt length priorities be in the order 9", 3", 5". The reasons are obvious.

(d) In regard to testing machines, it is clear that the joints program will require a great deal of testing time. Because the small clear specimen tests will also require considerable testing time, it is possible that a bottleneck can occur in regard to testing facilities. To prevent this, the researchers in Ecuador have decided to use a small portable tester (of the type used for concrete cylinder tests) to supplement their use of a testing machine. This appears to be quite satisfactory as the hydraulic loading system is capable of providing the required accuracy. It is recommended that the other Laboratories consider the possibility of doing the same if there appears to be a slowdown in the progress of the testing.

N.B.

(e) It is hoped that this Subproject on the resistance of simple nailed and bolted joints will be only the beginning of years of testing and development for joints in tropical hardwoods. Possible topics for future testing (in order of priority) are:

(i) durability and corrosion of fasteners. This one is critically important and it is hoped that work can begin on this as soon as possible. Several aspects are worthy of attention - general corrosion (oxidation) of metal fasteners, chemical corrosion of fasteners due to a combination of moisture and chemicals in the wood, and degradation of the wood itself ("nail sickness") due to chemical attack by corrosion by-products. For this purpose, it is suggested that extra test specimens be made up during the nail and bolt program and set aside in various environments for varying periods of time, and then examined and tested in an attempt to detect loss of performance with time.

(ii) connector groups. It is known that the capacity per connector decreases as the number of connectors in a joint increases. The severity of this is somewhat species-dependent and so, it is hoped that work on various group configurations and sizes can begin at an early date.

(iii) perpendicular-to-grain strength of nails. It is not known, for tropical hardwoods, how much weaker (if at all) this loading is than parallel-to-grain loading. Until this information is available, it would appear to be safe to permit loads for perpendicular-to-grain loading equal to 80% of parallel-to-grain loading.

(iv) effect of moisture content on strength. Eventually, tests should be conducted on wood in the dry condition.

(v) split ring and shear plate connectors. It will be helpful to the development of fully-engineered (e.g., long-span) structural systems if reliable load-carrying and performance data are available for these types of connectors used in tropical hardwoods. With respect to corrosion considerations, it might be necessary to require galvanizing.

(vi) development of regional standards for nails and bolts.

(vii) fatigue behaviour of joints and energy absorption during testing. This is information essential to proper design against seismic loading.

(viii) truss plates. For the economical in-plant prefabrication of light roof trusses, these toothed plates are invaluable. However, because of the higher wood densities being considered, the author is not optimistic about much progress in this area.

(ix) glued joints. In-plant joints and on-site joints should be considered separately, with a warning that quality control of on-site glued joints is most difficult to achieve.

(x) single-shear tests on nails. This is possibly a more common construction arrangement than double-shear loading, but the double-shear nail tests in progress will yield conservative results for single-shear loading.

(xi) use of high-density hardwoods in place of steel in joints. This is fairly promising developmental work for the future because of the availability of high-density hardwoods and the elimination of many types of corrosion problems. (There are examples of this being done in the United States, e.g., a timber trestle and truss structure supporting an antenna could have no metal parts and so the bolts and nuts were made of wood-based composites.) But perhaps the first type to consider would be a wood disc to act similarly to split-ring connectors.

6. DESIGN OF WOOD STRUCTURES

6.1 Proposed Program of Work

The major objective is to prepare the Cartilla, i.e., a manual describing the principles and methodology of wood construction using the 100 tropical hardwood species being studied. The Cartilla will be very broad in its scope, including urban planning and architectural design (the proper locating of wood houses on lots and in developments, considering solar radiation, ventilation, fire performance, etc.) and structural design (how to select structural systems and members, and how to fasten and protect these systems).

p.8 The Cartilla will be the focal point of a regional program of public education and promotion, which will address itself to the widest possible audience: craftsmen, contractors, educational institutions, government officials and financial institutions. The Junta and the counterparts will attempt to develop and nurture an infrastructure of people in the above categories who are knowledgeable about the proper use of wood in construction, so that the momentum generated by the Project will continue to grow to the benefit of the region.

It is hoped also to encourage demonstration projects such as wood housing and industrial buildings of heavy timber construction. In regard to housing, the Junta has elected to concentrate on middle-income housing in an attempt to remove the stigma of wood being the "poor man's building material". In so doing, it differs philosophically from, for example, the FAO project in Venezuela which appears to be more concerned with low-income housing.

Another objective of this Subproject is to carry on a testing program for full-size structural elements, panels and components as an aid to design, particularly design against seismic loading.

Development of design criteria for buildings is another task of the Design Subproject; this includes both structural loads and general service requirements, e.g., climatic consideration.

6.2 Comments

(a) A clear distinction should be made between the design of engineered structures (e.g., industrial buildings, commercial buildings, assembly buildings, bridges, towers, trestles, earth-retaining structures, cribs, wharves, etc.) and the design of semi-engineered structures (e.g., housing). One of the important differences is the degree of standardization which is possible in the two systems. A fairly typical situation in North America is that a national housing authority will specify the minimum requirements for housing and this extends to the specification of grades and sizes for individual structural elements; the basis for this specification includes considerably more than strength acceptability - also considered are static and dynamic stiffness, thermal and acoustic insulating value, fire performance, consumer preferences, and durability. In contrast to this, engineered construction is generally governed by a building code which specifies allowable stresses and deformations, among other things, and requires that the design be carried out by a professional engineer. In this situation, rarely is much standardization possible, and the process depends heavily on principles of mechanics.

p.3. It is recommended that the workers in both the Design and Grading Subprojects consider observing the above distinction as they develop the Cartilla. It is likely that they will find that the design criteria should be different for the two types of construction, and that safety and economy will be better achieved by this separation.

(b) With respect to demonstration projects for engineered construction in wood, it is strongly recommended that long-span structures (e.g., trusses, arches) as well as more complex systems (arches, shells, folded plates, lamella roofs) be not attempted in the near future. In North America, failures of this class of structures are proportionately much higher than for any other type of wood construction. Consequently, the Junta is urged to defer encouraging this type of construction until several years of satisfactory experience with simple short-span structures have been achieved.

(c) The Cartilla should be modular in its construction, with the ability to easily replace or insert individual sections. This will facilitate updating the Cartilla as revisions and additions are made to it, and will afford better control over the edition which is currently in effect.

(d) Any particular section of the Cartilla may be written in different versions, depending upon the intended audience. For example, if there is a section on Nailing, the manner in which this material is presented to carpentry or construction students and craftsmen will be substantially different from the manner in which it is presented to architects and engineers.

(e) As a possible model for design aids such as charts and graphs, the author recommends referring to the Timber Design Manual published by the Laminated Timber Institute of Canada, a copy of which was given to the Junta in November 1975.

(f) In order to make the most effective use of the funds available, it is recommended that photographs, drawings and graphs in the Cartilla be produced in black-and-white, and not in colour.

(g) As mentioned earlier, the amount of information on connections to be generated by the Project is not extensive and a considerable commentary should be produced to warn designers about the consequences of extrapolating the basic data. Typical warnings would include some mention of the size or group effects on the capacity of joints, the possibilities of corrosion, the non-uniformity of nail and bolt types being tested, the effect of duration of load, the effect of load orientation, etc.

(h) The author has been asked to offer an opinion regarding the proper respective roles of the Junta personnel and the national counterparts in the Design Subproject. The essential roles seem to be that the Junta will prepare the Cartilla and the counterparts, with the Junta, will concentrate on building up the infrastructures in the various countries to make use of the Cartilla. But the role of the counterparts need not wait until the Cartilla is finished; the groundwork in establishing greater emphasis on wood construction at the universities and technical schools can begin immediately (and, in some cases, has already begun). In addition, links with officials of financial institutions and governments (particularly the housing ministries) can be enlarged upon to alert them to the forthcoming technology. In this connection, it appears that in Venezuela, a stronger coordination between the FAO architectural project in Caracas and the wood technology work in Merida would be mutually beneficial, and it is recommended that steps to be taken to achieve this. Another role is in respect to the Glossary of Terms to appear in the Cartilla; the counterparts can identify local terminology which is in conflict with the Glossary, and so aid the Junta writers.

(i) With regard to prefabrication and modular coordination, these should be encouraged for residential construction but probably not for other types of wood construction, again for reasons of natural standardization of structural elements. The production facilities for these, in the author's opinion, should be close to the market and not to the resource. (In this, the author disagrees with the recommendation of Mr. Brealey in an earlier report on the Forestry Technology Project.) The reason for this is, if it is close to where the units are being used, the production of prefabricated components is more sensitive to the inevitable on-site problems, and can provide remedies more efficiently.

This market proximity is even more desirable where there are large concentrations of population, e.g., Lima, than is the case in Canada where the population is more dispersed. Finally, the shipping of prefabricated components like roof trusses usually involves a less dense (and less economical) shipping arrangement and therefore transportation distances for prefabricated units should be less than those for rough lumber.

(j) Questions were raised concerning additional laboratory facilities for the Junta in connection with the Design Subproject. The first of these deals with facilities for testing full-size structural members by means of portable hydraulic equipment. This equipment could be used for beam tests (e.g., solid beams, built-up beams) as well as for tests on floor, roof and wall panels. This is an excellent proposal and should be encouraged as long as the equipment retains its ability to be used for several different types of tests.

ACTION IMP

The other proposal was to build a "shaker table" for simulating seismic loads on house modules. In view of the fact that a seismic testing unit will be installed in Caracas, and assuming that it will be available to the Subproject workers, an additional facility in Lima would seem to be an unnecessary expense.

(k) Future work in the development of design procedures could study "load-sharing" systems, i.e., load distributions in redundant systems, and "progressive collapse", i.e., how to prevent the failure of one structural element from causing the overall collapse of the structure. In this latter case, the proper role of structural joints is very interesting: should they function, under some abnormal conditions of loading, as structural "separators" or as elements with extra ductibility and energy-absorbing abilities?

(l) Encouragement should be given to the development of permanent associations to facilitate communication among the various infrastructures. Three types are possible:

(i) a scientific/technical society: similar to the Forest Products Research Society. Since FPRS is already an international society, one possibility could be to form one or two new sections of FPRS in South America. On an individual basis, there is now considerable communication between Project individuals and the FPRS, as well as an active involvement of FPRS in problems of tropical wood utilization.

could be discussed in meetings?

(ii) a standards association: similar to the Canadian Standards Association. This non-governmental organization promotes the voluntary standardization of a great range of industrial products including wood products. Its major approach is to set up committees of balanced representation - producers, consumers, engineers, researchers - and to seek consensus. In the present case, such standardization attempts could extend to grading rules and allowable stresses, fastenings for wood construction, and lumber and panel sizes.

(iii) a trade association: similar to the Canadian Wood Council or to the Council of Forest Industries of British Columbia. This is an association of producers of wood products who are interested in jointly promoting their products. This is accomplished through the preparation of educational materials, by advising governments, financial institutions and standards associations, and by (and this is most relevant to the Project) having field representatives available to solve on-site construction problems and to assist educators and designers. These people retain their credibility by not being part of the sales staff of the producers.

(m) Another area for future development work concerns the use of structural panel products like plywood and particleboard. Of these two, the latter product may be the one to concentrate on, first, because it makes more efficient use of the wood fibre resource, and secondly, because of the greater range of products of varying density and configuration which can be developed. It may be of interest to note that, in North America, exterior particleboards are encroaching substantially on traditional plywood markets.

(n) The author is delighted to see that structural designs prepared in North America and Europe are not being copied unquestioningly. The Project design team is very much aware that these designs evolved in response to structural requirements possibly quite different from those of the Andean Pact countries and have very sensibly decided to develop their design process from their own particular design criteria.

Nevertheless, it might be useful for some of the workers in the Project to be more aware of the considerations and problems faced in the preparation of the Canadian wood design code, which is the responsibility of the Canadian Standards Association Committee for Standard 086, "Code of Recommended Practice for Engineering Design in Wood." This committee is meeting in Ottawa April 21-23, 1976, and Project personnel would be most welcome to attend as observers. The author recommends that this trip be approved by IDRC, and would be prepared to escort the visitors during their stay in Ottawa.

(o) A final word on communication: it is the author's intention to continue to correspond directly with individuals in the various countries visited, to supply publications of interest and to inform them of educational and training opportunities as they occur. It is hoped that the IDRC will also regard the author's involvement in correspondence as a continuing situation and that he be kept informed of progress in the Project.

APPENDIX A

Project Personnel

Grading (Subproject 3.2)

Junta:

Subproject Chief:	Jose Carlos Cano
Wood anatomy:	Ana Maria Sibille
Tables of structural values:	Fernando Alvarez
Counterpart in Bolivia:	Luis Enrique Goitia
Counterpart in Colombia:	Alvaro Morales
Counterpart in Ecuador:	Juan Herrera
Counterpart in Peru:	Raul Parraga
Counterpart in Venezuela:	Gustavo Delgado

Design (Subproject 3.3)

Junta:

Subproject Chief:	Luis Takahashi
Structural Design:	Roberto Machicao
Urban Planning:	Juvenal Baracco
Architectural Design:	Christian Arbaiza
Counterpart in Bolivia:	Rolando Troche
Counterpart in Colombia:	Fabio Verastegui
Counterpart in Ecuador:	Eduardo Nina
Counterpart in Peru:	Isabel Moromi de Echazu
Counterpart in Venezuela:	Julio Cesar Centeno

Connections (Subproject 3.4)

General Coordinator:	Julio Cesar Centeno, Venezuela
Peru:	Wilder Valenzuela (La Molina)
Ecuador:	Nelson Toledo (Conocoto)
Colombia:	Jose Lastra (Bogota) Octavio Lopez (Medellin)
Bolivia:	Hector Claure (La Paz) Rolando Goitia (La Paz)

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UNIVERSITY OF TORONTO

Faculty of Forestry and
Landscape Architecture

THE STRUCTURAL UTILIZATION OF HARDWOODS
IN THE ANDEAN PACT COUNTRIES:
REVIEW NO. 2 OF THE FORESTRY TECHNOLOGY PROJECT

by

F. J. Keenan, P.Eng.
Associate Professor

Submitted to:

The Director
Agriculture, Food and Nutrition Sciences Division
International Development Research Centre
Ottawa, Canada.

January 21, 1977

Sesquicentennial
1827-1977

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CONTENTS

1. INTRODUCTION

The author was retained by the International Development Research Centre under the following terms of reference:

(a) to travel to Lima, Perú, for the period October 20 to 31, 1976, to review the activities of the Centre-supported Forestry Technology Project being carried out by the Junta del Acuerdo de Cartagena pertaining to timber design and engineering;

(b) to advise the Project staff on the testing methods to determine the strength properties and allowable stresses for structural timber;

(c) to advise the Project staff on the testing program for full-size structural elements;

(d) to provide guidance and assistance in the analysis of data and interpretation of the results of the various tests; and,

(e) to undertake such other assignments as are agreed upon between F. J. Keenan and the Centre.

Included in this last item was a request to advise upon the desirability of bringing other consultants to the Junta to assist with the work on design and testing, and the proper timing of these visits. The author was also requested to review the work proposed in the second phase of the Project and to comment on the proposals.

In carrying out this consultancy, visits were made in Lima to:

(a) the offices of the Junta;

(b) Laboratorio de Ensayo de Materiales, Department of Civil Engineering, Universidad Nacional de Ingeriería;

(c) the wood technology laboratories, Universidad Nacional Agraria La Molina;

and the following were interviewed:

Sr. Marcelo Tejada, General Coordinator
Sr. José Carlos Cano, Coordinator, Subproject 3.2, Grading
Sr. Luis Takahashi, Coordinator, Subproject 3.3, Design
Sr. Roberto Machicao, Specialist, structural design
Sr. Juvenal Baracco, Specialist, architectural design
Sr. Sergio Alandia, Specialist, mechanical engineering
Sr. Christian Arbaiza, architectural design
Sr. Fernando Alvarez, specialist, structural testing
Sr. Wilder Valenzuela, specialist, joint testing at Universidad Agraria La Molina

I wish to express my sincere appreciation to all of the individuals listed above, and to the other Project personnel I met, for their complete cooperation and hospitality during my visit.

As indicated in the title, this report is the author's second review of the Forestry Technology Project; the first review is dated February 2, 1976. Readers are referred to this earlier report for descriptions of the overall objectives of the Project and of the methodologies to be followed in Subprojects 3.2 (Grading), 3.3 (Structural Design) and 3.4 (Connections).

The principal personnel are listed in Appendix A.

2. GRADING OF CONSTRUCTION LUMBER

2.1 Present Status

(a) Sr. Cano has developed a preliminary standard for the classification of structural timbers, according to their expected bending strength properties in service. It involves, first, a classification of each species into one of a number of species groups. These groups segregate species according to basic strength properties. Within a species group is a further classification into Grade I, Grade II (and Reject), which is based on the defects (eg. knots, decay, insect attack, brittle heart, splits, wane, slope of grain, warp, pith, checks, etc.) present in the piece. This grading rule is in Appendix B of this report.

The next step is to determine the strength of several pieces of wood within each grade and species, so that a database can be generated which will provide a dependable estimate of the "near-minimum" strength of that grade and that species; on this value is based the determination of the allowable stress. This has been done by Sr. Cano (and will be done by his counterparts in each country) by going to the local lumberyards and obtaining 20 pieces 7 cm. x 20 cm. x 340 cm. long of each of approximately 60 species. The pieces are then tested, in the green condition, in static bending to determine the modulus of rupture, the modulus of elasticity and the stress at the proportional limit.

This testing has two purposes: in addition to its eventual use in determining allowable stresses as mentioned above, it is also used to check the efficacy of the proposed grading rule in predicting the relative bending strengths of structural members of various grades. For this second purpose, the analytical technique is to assign a rank to each of the 20 beams tested, number one being the strongest and number twenty being the weakest, and then plotting the strength of each versus its rank. Then, beside each plotted point is shown the grade (I, II, or R) that was determined for that member. If the grading rule were to work perfectly, all of the grade I points would lie above all of the grade II results which, in turn, would lie above all the Reject beam results. For a sample of the test data examined by the author, this behaviour <u>was</u> found to exist. In the few cases where it did not, an examination of the original test data, defect records and beam photographs usually explained the anomaly, and this discovery led to a slight revision of the grading rule or of the grading process carried out in the laboratory. At the present, then, the grading rule is working satisfactorily for the 220 beams, comprising 11 species, which have been tested at the Universidad Nacional de Ingeniería in Lima.

At the time of the author's visit, Sr. Cano was about to visit the other countries to supervise the grading and testing of the remaining beams. It is expected that this testing will be completed by February 1977, and the final species groupings and grading rules promulgated by March 1977.

The determination of allowable bending stresses will then proceed by taking the "near-minimum" value of bending strength (the fifth percentile) for all of the test data for a particular species group and grade and then dividing by a factor of safety. The factor of safety is a variable and its value depends upon the type of construction (eg. load-sharing vs. non-load-sharing), the consequences of failure (eg. public assembly building vs. an agricultural storage building), and the presence of ductility (if any) displayed by the beam between initial failure and final failure (this has obvious implications for seismic behaviour).

(b) The paragraphs above describe the testing of full-size beams in the various laboratories. Originally it was proposed to test an approximately equal number of full-size columns. After further discussion and some preliminary tests, it was realized that the testing of columns is not as important as the testing of beams because the strength of columns is not as sensitive to the presence of defects as is the strength of beams. Moreover, in practice, columns are not generally loaded to their full allowable stresses nearly as often as beams. Thus, to best utilize the resources of time, manpower and laboratory equipment, it was decided to reduce the proportion of column tests in the program to not more than 30% and to do this work after the beam tests. Anticipated completion is the end of February, 1977.

(c) As mentioned above, the species being considered are segregated into one of a number of species groups. This initial separation was done on the basis of physical and mechanical properties already known, but it is expected that these groups will be enlarged and possibly adjusted when all of the data from Subproject 3.1 has been received. A certain amount of common sense and trade-offs will be needed here; for example, a particular species may not have adequate strength properties to qualify for a certain group but may possess some other quite good characteristics (eg. durability, stability during drying). Consideration would then be given to adjusting the group boundaries, and consequently the allowable stresses for the group, to accommodate this species. This will obviously be an on-going process.

(d) This may be an appropriate point at which to describe the proposed process for standardization of construction wood products. At the present time, there are virtually no standards of this type within the Region. The Junta's approach is to develop proposed standards on the basis of the research and development work of the Project, and then, via the national chiefs of the project or the Dirección Forestal, to transmit these to the Instituto de Normalización in each country for their consideration and acceptance. Following national acceptances, (which are estimated to take no more than six months), the standard will be submitted to COPANT (Comite Panamericano de Normas Tecnicas) as a subregional proposal. At the moment, approximately 37 wood construction standards are being developed, of which eight are related directly to the Grading Subproject. Eventually it is hoped that the responsibility for administering individual standards will be assigned to separate countries, rather than to the Junta.

(e) Another activity within the Grading Subproject is the identification and description of all the 200 species being studied in the Project. This work is proceeding well, with material being produced describing each species' botanical characteristics, macro- and micro-characteristics, and the means for its indigenous and scientific identification. It is proposed that a publication be prepared to present this material, separate from the Cartilla, along with the other information being developed for each species in the Project (eg. physical and mechanical properties, drying characteristics, workability, etc.). Estimated completion for this activity is Spring, 1977.

One objective of this work is to correlate the scientific names of the species tested with the common names which are used in the various countries. This step is essential if any subregional coordination is to take place. However, it has another benefit -- with the test results obtained to date, it is evident that some species display considerable variability in their properties depending upon the location of growth. Information of this type will lead to a greater understanding of the influence of growing conditions and possibly of genetic influences on wood quality. A chart showing the correlation of scientific names with national common names is included as Appendix C; the names underlined are those being tested in the Project.

(f) As input to this process of species identification, the sawmill survey being conducted in the various countries, as described in the author's previous report, is making a substantial contribution. Information is being generated from this work which assists in the "folk" identification of the trees themselves and also in the vernacular identification of the defects contained in the lumber produced. This latter material will appear in the Glossary of the Cartilla. Thus, this work supports both species identification and the methodology of lumber grading. In November 1976, Perú, Bolivia and Ecuador had submitted their results from the survey.

2.2 Comments

(a) Simply, this Subproject is proceeding very well. The volume of work, the pace of the work, and the probable completion date, are all satisfactory. The results are original and will be immediately useful in structural engineering. The approaches and methodology adopted by Sr. Cano are an intelligent distillation of all the advice (often conflicting) given by the various advisors to the Project.

As was mentioned in the author's original review of the Project, the processes of classification and of establishment of allowable stresses are on-going, and must continually take into account new test data on full-size members, geographic variation in species properties, and evolving philosophies in regard to structural safety. For this reason, it is hoped that, after Phase I of the Project has been completed, some mechanism can be developed for the continuation of this activity.

Incidentally, during further testing, consideration should be given to the other uses to which lumber from these species can be put, eg. planking and decking, containers, etc. There is a very high consumption of wood in the sub-region for plank formwork and, in fact, wood is currently being imported for this purpose. Because all that is needed for this application are flatwise strength and stiffness bending properties, the wood resource could actually be utilized for this use before the Project is complete.

In this regard, it should be mentioned that major work on the testing of full-size, in-grade populations of structural wood products, and the corresponding re-formulation of structural grading and safety concepts, is now proceeding in Vancouver, Canada in two locations: at the Western Forest Products Laboratory (under Mr. T. W. Littleford) and at the University of British Columbia (under Professor Borg Madsen). It is strongly recommended that arrangements be made for Sr. Cano to visit these two projects. This Canadian work will probably bring about substantial changes in our traditional approaches to timber engineering; the Project would benefit significantly through direct exposure to this research. It appears that the best time for such a visit would be early 1977. The author would be happy to assist with the negotiations for the visits and could possibly arrange to accompany Sr. Cano in Vancouver.

(b) The author was permitted to see a draft of Dr. Kauman's latest report on the Project. In it, he discusses the Grading Project activity and the importance of various defects, and states:

> "En muchos países tropicales, se da una exagerada atencíon a nudos y al esparciamento de los anillos, por analogía a sistemas de clasificación de países del hemisferio norte. Estos dos defectos, por lo general, son de poca importancia en maderas tropicales."

In regard to knots, the author respectfully suggests that this statement should be treated with caution; although knots, of course, occur much less frequently in tropical hardwoods than in temperate conifers, their effect on bending strength (particularly if located at an edge of the tension face) is most considerable. A startling example of this effect was seen when examining the Peruvian beam test data.

(c) The proposed publication on the identification and technical properties of the species being investigated will require colour plates in order to properly present the information on species identification. This is an obvious exception to the author's general contention that colour printing is not financially justified for technical publications.

(d) The original working plan for the grading subproject was very flexible and did not pin down precisely all of the activities to be followed. This is not generally advisable for short-term research, but in this case it has proven to be wise -- the development of lumber classifications and grades and the derivation of allowable stresses are iterative processes which require re-evaluation and adjustment repeatedly as information about the resource unfolds during the progress of the research. In other words, this was really "research development", and not routine testing, which is all that would have been required had the mistake been made of automatically accepting the North American grading rules. This also confirms that the right decision was made in having the work done centrally by the Junta rather than as a cooperative effort over the Sub-region.

3. DESIGN OF WOOD STRUCTURES

3.1 Present Status

There are three major activities within this Subproject: architectural design and urban planning; development of technical proposals for improvements in wood construction practice; and a testing program for static and dynamic behaviour. Each of these will be discussed in turn.

(a) Architectural Design and Urban Planning

This work, being carried out by Sr. Juvenal Baracco, has three aspects: climatic zonification, modular coordination, and urban planning. In climatic zonification, he has examined all the environmental factors which affect human comfort in housing, eg. relative humidity, mean temperature, diurnal temperature ranges, prevailing winds, solar radiation, vegetation, rainfall, and has formulated a system of eleven bioclimatic zones for the Subregion. These will determine the architectural design characteristics for housing in each zone eg. thermal insulation, ventilation, ground clearance, and directional orientation of housing. This work is essentially complete as far as the Junta is concerned; what is needed now is a critical review by an outside advisor and this is being requested.

In modular coordination, Baracco has studied the available literature, and having considered this in the light of regional needs and possibilities, has identified a precise list of relevant details for design, fabrication and construction where quantification is required. This is as far as he feels he can go without outside advice from an expert in this field, and is therefore requesting a visit as soon as possible.

In urban planning, the world literature is extensive, and Baracco is reviewing this in terms of local requirements and this work is nearing completion. No outside advice is requested.

(b) Development of Technical Proposals for Improvements in Wood Construction Practice

Sr. Luis Takahashi and his design team have elected not to propose radical new housing schemes and construction methodologies at this time. Rather, their intention is to emphasize improvements to already existing technology and methodology. In other words, their approach has been to examine carefully and critically all of the methods of traditional wood construction in the Subregion, to evaluate whether they work well or not (particularly in regard to durability and seismic response), to identify the factors involved in performance, and finally to devise methods of improving traditional construction. This last step is accomplished both from the extensive experience of the team and also by means of static and dynamic testing (discussed below). This material will then appear in the Cartilla; it may be thought of as comprising five sections:

(a) description of construction and structural and material behaviours,

(b) a technical explanation of the behaviours described in (a),

(c) technical proposals for improving wood construction,

(d) engineering data, and

(e) the Glossary

Parts (a) and (b) are essentially complete; parts (c) and (e) are partially complete now and were expected to be finished by December 1976; part (d) will include the results of the testing which will have been completed by June 1977.

Now that the production of the Cartilla is well under way, it is clearer than it was a year ago what the objectives, approaches and contents are, and it is probably worthwhile to spend some time describing these. First, the potential audience consists of three large groups: the producers of forest products which can be used in construction, the construction sector (architects, engineers, builders), and the consumers. (It is interesting to note that the governments are in all three sectors.) Each of these groups has its own particular needs -- among other things the producers need standards and specifications for the manufacture of wood construction products, the construction sector needs standards and the technology of wood construction, and the consumer need building codes, both for his own protection and for obtaining mortgage funds. The codes and standards will be published separately (as described earlier) and the Cartilla will concentrate on how to design and how to build with wood. It will contain information on wood as a construction material, the architectural factors in using wood as a construction material, and the structural design of wood to fulfill the architectural requirements. Included in the Glossary will be technical terms agreed upon within the Subregion and a section on the graphical representation of structural details. As indicated above, it will contain an examination of known factors and an encounter with factors and behaviour not well known. Because wood construction in the Subregion has no present technical support (and therefore little financial support), the project objectives are to provide the technical basis for what is now working well. In terms of changes to this technology, this means that a house builder will be able to make small changes based on improved information, but an engineer will have the foundation for major developments in the future.

(c) Testing Program for Static and Dynamic Behaviour

Under 3.2 "Comments" below are described the extensive discussions held between the author and Sr. Takahashi and Sr. Machicao dealing with structural behaviour and design. From the talks, it was possible to formulate a detailed working plan for the structural research required for the satisfactory completion of Phase I of the Project. Because of the importance of this document, it is included in the Report as Appendix D. Estimated completion date is June 1977.

(d) It was reported to the author that the development of professional infrastructures -- architects and engineers -- is progressing well through the activities of the design subproject counterparts in each country.

3.2 Comments

(a) Climatic Zonification

The author's experience in tropical architecture is virtually non-existent, but, as a layman, he found the work done to appear sensible and appropriate. The argument for an outside advisor was compelling, and it is therefore recommended that steps be taken immediately to engage one of the following (in order of priority):

(i) Givoni, Israel
(ii) Koenigsberger, England
(iii) Ingersoll, England
(iv) Frager, Denmark

(b) Modular Coordination

Similarly, the work done in modular coordination seems to have progressed as far as it can without outside assistance, and it is recommended that one of the following be brought to Lima as soon as possible (again in order of priority):

(i) Lund, Norway
(ii) Sheppard, England
(iii) Rabeneck, England
(iv) Crocker, England

(c) Development of Technical Proposals for Improvements in Wood Construction Practice

The question of whether the material to be contained in the Cartilla is "promotional" or "research" was raised and the author was asked to comment. After examining samples of the material to be included in all five sections, it is clear that parts (a) and (b) rely upon information now existing publicly in one form or another, and, although it has been carefully compiled and edited, it is certainly not research. In contrast, parts (c) and (d) will contain original information which has been obtained either experimentally or through a synthesis of experience and technical speculation. Thus, in a real sense, parts (c) and (d) are the products of experimentation and contemplation, ie. research. Part (e), the Glossary, in the author's opinion, is also research but of a different kind: it has required a study of the several technical vocabularies of the Subregion and a compilation and standardization of these. This is original work and is technically essential for the Project. Parts (c), (d) and (e) will comprise approximately half of the Cartilla.

The question of whether certain material is "promotional" or "research" is understood to be related to IDRC's mandate and to its role in funding the Project. Going beyond this consideration, it must be recognized that all parts of the Cartilla are a valuable contribution to the accomplishment of the aims of the Project, and thus all of this material should be published in some manner or another. Thus, it would appear to be in the interests of IDRC to assist in the seeking of other financing to enable all of this information to be published. (This recommendation applies also to the publication of the 'Cartilla Elemental' which is clearly a promotional vehicle, but which nevertheless can play a significant role in achieving some of the long-term objectives of the Project.)

However, if it becomes not possible to publish the full Cartilla, it is necessary to determine the shape of the compromise. One possibility could be to publish a 'Cartilla para Usarios', a manual for technical users which is essentially a report on the research and development achievements of the Project with a minimal amount of background technology. Specifically, it would consist of a drastic condensation of parts (a) and (b), constituting 20%, and parts (c), (d) and (e), constituting 80%. This is a possible solution but it must be emphasized that it is a poor second choice to the original concept of the Cartilla.

The author spent several days with Sr. Takahashi and Sr. Machicao discussing one by one, the large volume of new technical proposals formulated to date. It was a stimulating and enlightening experience -- the work that has been done is absolutely first-rate! In many cases, the proposals were concurred with, in other cases they were modified, some new ones were developed, and some were deferred until after some test results become available. The publication of this information will make a significant contribution to the world literature on tropical construction. This exercise was too extensive and too detailed to reproduce in this report, but it could be mentioned that discussions treated matters of load transfer between structural elements, stability, durability, seismic performance, etc, as would be inferred from a perusal of Appendix D.

(d) Testing Program for Static and Dynamic Behaviour

It became increasingly obvious during this consultancy that the number one priority research area in the Sub-region is response to seismic loading. During the previous visit, one year ago, it was thought that the shaker table in Caracas could be used for this research and therefore, the installation of such a facility in Perú would be superfluous. This was a misconception; the machine in Caracas is too small, in the author's opinion, for the type of research actually needed for wood construction. Moreover, it appears that the Venezuelan facility does not have the appropriate control over frequency and amplitude of vibration.

A second important factor is that, again in the author's opinion, research on this type of wood construction must be done on full-size specimens, and not models as is the case for metals, concrete and plastics. The reason is that the effects of defects, structural joints and energy-absorbing characteristics in wood construction are not amenable to the application of scale factors. (This is also true of static testing.) The author therefore strongly recommends that a facility for the seismic testing of full-size timber structures be assembled as soon as possible in Lima.

A specialist in seismic behaviour is needed to advise the team at this point. It is strongly recommended that either Professor Sugiyama or Izuko be retained as soon as possible. Because both the seismic tester design and the working plan for the research are completed, it is appropriate that this consultant come as soon as possible.

The detailed design of such a facility was discussed at length with the group, and particularly with Sr. Sergio Alandia, a mechanical engineer with the team. Considerable work has been completed to design this facility and a great deal has been learned by the group as a whole as a result of the exercise. The next question is whether all or part of the facility can be fabricated in Perú and what components should be purchased. These options were also studied at length and the final recommendation is included as Appendix E of this report. Essentially, the tester will provide one mode of movement (one translation) with separate control over amplitude, frequency and functional shape of the excitation, with specimen translations being recorded via displacement transducers. What is proposed appears to be a minimum cost facility for the necessary research work. Moreover, purchasing the Instron equipment will permit the use of the activators ~~for other research activities and~~ can be improved in the future, eg. the addition of vertical movement. The "made-in-Perú" alternative is characterized by lack of versatility and is not recommended.

4. PHYSICAL, MECHANICAL AND JOINT TESTING PROGRAMS

4.1 Present Status

With one important exception, this work is reported to be progressing satisfactorily and will be completed prior to July 1977. The exception is at La Molina where the work has been severely slowed by log collection problems. At the present rate of progress, there is no way the work can be completed by the deadline. However, the Junta seems to be alarmed at this state of affairs, and is sympathetic to the idea of pumping more money into the effort to put on an extra shift of workers, to purchase more supplies and testing equipment and to remove all obstacles to log delivery. In fact, at the time of the author's visit, the Ministers of Agriculture of the Andean Pact countries met and passed a resolution to all increase their contributions to the Project in order to speed up the work and assure completion of the Project by the deadline. The text of the resolution appears in Appendix F.

4.1 Comments

(a) The problem at La Molina seems to be the weak link in the Project right now. Everything else seems to be proceeding towards an anticipated completion date of June 1977; at La Molina, everything will have to go right and at full capacity with two shifts in order to finish by June 1977.

(b) It may be worthwhile to consider sending some of the laboratory personnel to other laboratories for short training sessions to broaden their exposure to mechanical testing of wood products and thereby to improve their technical judgement and self-reliance. It seems that only short-duration courses or visits are needed at this stage because great depth of extra training is not necessary right now, and because it is desirable to interrupt the testing programs as little as possible. It is an obvious advantage for these courses to be attended within South America if at all possible.

to expand these comments if possible

5. PHASE II RESEARCH

5.1 Proposals

It is proposed by the Junta that the Forestry Technology Project enter a second phase beginning July 1, 1977, with some preliminary planning work being done in the period January to June, 1977. This work is outlined in a document for discussion entitled 'Estudio Integral de la Madera para Construccion (Segunda Fase)' dated July 1976. The author reviewed an English translation of this document. The work proposed is essentially a continuation and an extension of the work of the first phase. Some of the activities proposed are the following:

(a) the continuation of the physical, mechanical and joint tests of the first phase to 10 additional species per country, for a total of 50 new species,

(b) the design and testing of prototype housing and other structures for each country based on the results of the first phase, structural components

(c) the continuation of static and dynamic testing of structural elements and systems,

(d) the design of industrial processes for the large-scale fabrication and prefabrication of wooden constructional elements and systems, and

(e) the continuation of educational and promotional programs + TRAINING eg. through the nourishment of infrastructures.

5.2 Comments

(a) It is a "motherhood" response to say that the work of the Forestry Technology Project should proceed into a second phase, but it is clear that the results of the first phase are now in a most fragile state -- if there is no follow-up, the efforts expended will have been largely wasted. It is less clear, however, that the work proposed is the most urgent. Specifically, activity (a) seems less compelling than the others at this time. It is certainly useful to obtain all the data one can get from all the species one can collect, and it is useful to continue the momentum of the laboratories now engaged in this work, but it is not as critical as developing further the data already collected. Moreover, the author pointed out in his first review that he is not convinced that the mechanical tests other than static bending and compression parallel to the grain are particularly applicable to the design process.

(b) It would be a severe blow to terminate the Forestry Technology Project at the end of Phase I, but it would be almost as harmful to delay the start of Phase II: the professionals assembled by the Junta will quickly disperse if Phase II does not immediately follow Phase I. The expertise, the experience, the commitment to work will not be recoverable within a reasonable time, and the work will founder. It is the strongest recommendation of this report that the key people in the Junta team be kept together for Phase II.

problems of insecurity - morale - from work, etc. being felt at the moment -

Toyoda
Cano
Takahashi X

younger staff members could also do a good job -

APPENDIX A

Project Personnel

Grading (Subproject 3.2)

Junta:

Subproject Chief:	José Carlos Cano
Wood anatomy:	Ana Maria Sibille
Tables of structural values:	Fernando Alvarez
Counterpart in Bolivia:	Luis Enrique Goitia
Counterpart in Colombia:	Ramon Camargo
Counterpart in Ecuador:	Juan Herrera
Counterpart in Perú:	Arturo Astocondor
Counterpart in Venezuela:	Gustavo Delgado

Design (Subproject 3.3)

Junta:

Subproject Chief:	Luis Takahashi
Structural Design:	Roberto Machicao
Urban Planning:	Juvenal Baracco
Architectural Design:	Christian Arbaiza
Counterpart in Bolivia:	Rolando Troche
Counterpart in Colombia:	Arturo Londoño
Counterpart in Ecuador:	Eduardo Nina Gonzalo Bustamante
Counterpart in Perú:	Isabel Moromi de Echazu
Counterpart in Venezuela:	José Almandoz

Connections (Subproject 3.4)

General Coordinator:	Julio Cesar Centeno, Venezuela
Perú:	Wilder Valenzuela (La Molina)
Ecuador:	Nelson Toledo (Conocoto)
Colombia	Octavio Lopez (Medellin)
Bolivia	Rolando Goitia (La Paz)

REGLA TENTATIVA DE CLASIFICACION POR RESISTENCIA DE MADERA TROPICAL

CLASE I

- NUDOS

  A. Nudos sueltos, ahuecados, con corteza incluída, etc.

  1. En cara se permite 3 cm máximo de diámetro y no más de 1 cada 1 metro.
  2. En canto no se permite

  B. Nudos sanos, firmes, crece interiormente

  1. En cara se permite 3 cm máximo de diámetro y disperso a no menos 1 metro de distancia uno de otro
  2. En canto no se permite

- RAJADURAS

  Apareciendo en una cara de un extremo solamente y de longitud máxima igual a la mitad del ancho de la pieza.

- ACEBOLLADURA

  Permitida en una sola cara y de 50 cm de longitud.

- ALBURA SANA

  Permitido un perímetro máximo del 25% del perímetro total.

- ALBURA CON ATAQUE DE INSECTOS O PUDRICION

  No se permite.

- GRANO INCLINADO

  1. En cara o canto 1/10 se permite
  2. En dos lados adyacentes se permite máximo 1/14 y 1/14

- COMBADO

  Se permite 5 cm en 3 mts.

- ARQUEADURA

Se permite 2.0 cm. en 3 mts.

- TORCEDURA

Ligeramente

- ARISTA FALTANTE

Se permite 5 cm. de perímetro como máximo en 50 cm. de largo.

- MAL ESCUADRIA

No se permite

- MADERA COMPRIMIDA

No permitida.

- MEDULA O SIGNOS EVIDENTES DE CERCANIA A LA MEDULA (MADERA QUEBRADIZA, RAJADURAS LONGITUDINALES, etc.

No permitido.

- AGUJEROS DE INSECTOS TIPO AMBROSIA

Ligeramente y en una sola cara.

- GRIETAS(DE SECADO U OTRAS)

Muy ligeramente.

- AGUJERO DE INSECTOS DE 3 ~~CM~~ MM. DE DIAMETRO O MAS

Diseminado no más de 1 cada 50 cms.

CLASE II

- NUDOS

  A. Nudos sueltos, ahuecados, con corteza incluída, etc.

     1. En cara se permite 8 cms. de diámetro máximo y no más de 1 cada 1.20 m.

     2. En canto no se permite.

  B. Nudos sanos, firmes, crecen interiormente

     1. En case se permite 8 cms. de diámetro o mitad del ancho de la cara, el menor y disperso a no menos de 1.20 m.

     2. En canto no se permite.

- RAJADURAS

  Apareciendo sólo en un extremo y cona longitud máxima igual al ancho de la pieza.

- ACEBOLLADURA

  Se permite hasta un tercio del largo de la pieza sobre una sola cara y no mayor de 3cm de separación entre los anillos.

- ALBURA SANA

  Se permite hasta un tercio del perímetro total.

- ALBURA CON ATAQUE INSECTOS O PUDRICION

  No se permite.

- GRANO INCLINADO

  1. En cara ó canto 1/6 se permite

  2. En dos lados adyacentes se permite máximo 1/10 y 1/10

- COMBADO (EN CARAS)

  Se permite 3 cm. en 100 cm.

- ARQUEADURA (EN CANTO)

  Se permite 3 cm. en 3 mts.

- TORCEDURA

  Ligeramente

- ARISTA FALTANTE

  8 cms. de perímetro y a lo largo de máximo la medida de la pieza.

- MALA ESCUADRIA

  No se permite

- MADERA COMPRIMIDA

  No se permite

- MEDULA O SIGNOS EVIDENTES DE CERCANIA A LA MEDULA (MADERA QUEBRADIZA, RAJADURAS LONGITUDINALES, etc.

  No permitido.

- AGUJEROS DE INSECTOS TIPO AMBROSIA

  Moderado y disperso

- GRIETAS(DE SECADO U OTRAS)

  Moderado.

- AGUJEROS DE INSECTOS DE 3 CMS. DE DIAMETRO O MAS

  Moderado y no agrupado

ESPECIES DE LA SUB-REGION

Nº	NOMBRE CIENTIFICO	FAMILIA	BOLIVIA	COLOMBIA	ECUADOR	PERU	VENEZUELA	OTROS PAISES
1	Anacardium excelsum	ANACARDIACEAE		Espavel	Caracolí	Sachacasho	"Mijao"	Caracolí, espavé
2	Aspidosperma macrocarpa	APOCYNACEAE				"Pumaquiro"		
3	Bombacopsis quinatum	BOMBACACEAE		Ceiba tolua			"Saqui saqui"	
4	Brosimum alicastrum	MORACEAE					"Charo amarillo"	
5	Brosimum oblongifolia	MORACEAE	"MURURE"					
6	Brosimum uleanum	MORACEAE				"manchinga"		
7	Brosimum utile	MORACEAE		"Sande lechero"				
8	Calophyllum brasiliense	GUTTIFERAE	"Palo María"	"Aceite María"	María	"Lagarto caspi"	María	Lagarto, Sta María (Pa.)
9	Calycophyllum spruceanum	RUBIACEAE	"Guayabochi"					
10	Camnosperma panamensis	ANACARDIACEAE		"Sajo"	Sajo			Sajo
11	Carapa guianensis	MELIACEAE		"Guina tangare"	Tangare	Andiroba	"Carapa"	Crabwood (Guy
12	Carineana domesticaca	LECYTHIDACEAE				"Cachimbo"		
13	Carineana pyriformis	LECYTHIDACEAE	"Yesquero"	Abarco			Bacú	
14	Caryocar coccineum	CARYOCARACEAE				"Almendro"		
15	Cedrelinga catenaeformis	LEGUMINOSAE		Achapo	"Seique"	"Tornillo"		
16	Ceiba pentandra	BOMBACACEAE	"Mapajo"	Ceiba	Ceiba		Ceiba	Ceiba
17	Ceiba samauma	BOMBACACEAE				"Huimba"		
18	Cespedesia sp.	OCHNACEAE		Pacora	"Pacora"			
19	Chlorophora tinctorea	MORACEAE	Mora	Moral dinde	"Moral fino"	Insira caspi	Mora	[illegible] (Guy)
20	Chrysophyllum caimito	SAPOTACEAE			"Caimitillo"			

Nº	NOMBRE CIENTIFICO	[redacted]LIA [redacted]	[redacted] BOL[redacted]A [redacted]	[redacted]OM[redacted]	[redacted]ECU[redacted]	[redacted]	[redacted]VEN[redacted]LA [redacted]	[redacted]S P[redacted]ES [redacted]
21	Chrysophyllum sp.	SAPOTACEAE	"Blanquillo"					
22	Clarisia racemosa	MORACEAE	Mascajo	Aji	"Pituca"	Tulpay	Cajimán	
23	Copaifera officinalis	LEGUMINOSAE		Canima		"Copaiba"	Aceite	
24	Copaifera pubiflora	LEGUMINOSAE					"Aceite cabimo"	
25	Didimopanax morototoni	ARALIACEAE				Sacha uva	"Sun sun"	
26	Diplothrophis martiusii	LEGUMINOSAE				"Chontaquiro"		Tatabú
27	Dyalianthera gracilipes	MYRISTICACEAE		"Cuángare"	Cuangare			
28	Erisma uncinatum	VOCHYSIACEAE	Zapallo				"Mureillo"	
29	Eschweilera sp.	LECYTHIDACEAE				"Machimango negro"		
30	Eucalyptus globulus	MYRTACEAE	Eucalipto	Eucalipto	"Eucalipto"	Eucalipto		
31	Ficus glabrata	MORACEAE	"Bibosi"			Ojé		
32	Gallesia integrifolia	PHYTOLACACEAE	"Ajo ajo"			Palo cebolla		
33	Goupia glabra	CELASTRACEAE		"Chaquiro"				
34	Guarea sp.	MELIACEAE			"Piaste"			
35	Guarea trichiliodes	MELIACEAE		Bilibil		"Requia"	Trompillo	
36	Hieronyma chocoensis	EUPHORBIACEAE		"Pantano"	"Mascarey"			
37	Hieronyma laxiflora	EUPHORBIACEAE					"Carne azada"	SURADAN
38	Huberodendron patinoi	BOMBACACEAE		"Carra naguare"				
39	Humiria balsamifera	HUMIRIACEAE		"Olorosa"				Tauroniro, UMIRY
40	Humiriastrum procerum	HUMIRIACEAE		"Chanul"	"Chanul"			
41	Hura crepitans	HUMIRIACEAE	"Ochoó"	Lechosa		"Catahua amarilla"	Jabillo	SABLIER, SAND BO
42	Hymenaea courbaril	LEGUMINOSAE	Jakuhuayaka			Azúcar huayo	"Algarrobo"	Locust

N°	NOMBRE CIENTIFICO	FA[redacted]IA	[redacted]OLI[redacted]	[redacted]OMB[redacted]	[redacted]UA[redacted]	PE[redacted]	[redacted]NEZ[redacted]A	O[redacted] PA[redacted]
43	Inga affinis	LEGUMINOSAE	"Pacay"				Guamo	
44	Lonchocarpus sp.	LEGUMINOSAE	"Kaqui"					
45	Minquarthia guianensis	OLACACEAE		Punte candado	"Guayacán pechiche"			
46	Mora conggrijpii	LEGUMINOSAE					"Mora"	Morabukea
47	Mora megistosperma	LEGUMINOSAE		"Nato"	"Nato"			
48	Mouriri barinensis	MELASTOMACEAE					"Perhuétamo"	
49	Nectandra sp.	LAURACEAE				"Moena amarilla"		
50	Nectandra sp.	LAURACEAE				"Moena negra"		
51	Ocotea sp.	LAURACEAE	"Negrillo"					
52	Ormosia macrocarpa	LEGUMINOSAE				"Huayruro"		
53	Parquia sp.	LEGUMINOSAE			"Tangama"			
54	Peltogyne porphyrocardis	LEGUMINOSAE					"Zapatero"	Purpleheart
55	Pentaclethra macroloba	LEGUMINOSAE		"Dormilón capitancillo"				
56	Pinus radiata	PINACEAE			"Pino"			
57	Piptadenia macrocarpa	LEGUMINOSAE	"Curupau"					
58	Pithecellobium latifolium	LEGUMINOSAE			"Jibaro"			
59	Pithecellobium samán	LEGUMINOSAE		Samán			"Samán"	
60	Podocarpus oleifolius	PODOCARPACEAE			"Romerillo fino"			
61	Podocarpus rospigliosii	PODOCARPACEAE			"Romerillo azuceno"	"Romerillo macho"		
62	Podocarpus sp.	PODOCARPACEAE				"Romerillo hembra"		
63	Pouteria anibifolia	SAPOTACEAE					"Chupón rosado"	
64	Pseuldolmedia laevigata	MORACEAE		Leche perra	"Chimi"		Charo	
65	Pseuldolmedia multinervis	MORACEAE				"Chimicua"		

N°	NOMBRE CIENTIFICO	FAMILIA	BOLIVIA	COLOMBIA	ECUADOR	PERU	VENEZUELA	OTROS PAISES
66	Pterocarpus vernalis	LEGUMINOSAE					"Sangre drago"	
67	Sclerolobium sp.	LEGUMINOSAE				"Machimango blanco"		
68	Symphonia globulifera	GUTTIFERAE	Asufre	"Machare" Asufre	Machare	Asufre	Copeicillo	Manni (Guy) ANANY BARILLO, BOAR WOOD
69	Tabebuia roseae	BIGNONIACEAE					"Apamate"	
70	Taralea oppositifolia	LEGUMINOSAE	"Almendrillo"					
71	Terminalia amazonia	COMBRETACEAE	"Verdolago"		"Yumbingue"		"Pardillo amarillo"	Fukadi (Guy) AMARILLO DE Panama
72	Terminalia guyanensis	COMBRETACEAE					"Guayabón"	
73	Triplaris guayaquilensis	POLYGONACEAE		Fernán Sanchez	"Fernán Sanchez"	Fernán Sanchez		
74	Virola corinata	MYRISTICACEAE		"Otobo"				
75	Virola sebifera	MYRISTICACEAE	"Sangre de toro"	Chalviande	Chalviande	Cumala	Virola camaticaro	
76	Virola surinamensis	MYRISTICACEAE	Gabún				"Virola"	
77	Vochysia macrophylla	VOCHYSIACEAE			"Laguno"			
78	Vochysia ferruginea	VOCHYSIACEAE		"Sorogá"				
79			"Plumero blanco"					
80			"Coquino"					
81			"Serebó"					
82			"Tachore"					
83	Brosimum sp.	MORACEAE				"Panguana"		
84	Catostemma commune	BOMBACACEAE					"Baramán"	ADAURONA BAROMALLI

APPENDIX D

PROGRAMA TENTATIVO DE LOS ENSAYOS DE LABORATORIO DEL SUBPROYECTO 3.3

INTRODUCCION

Los ensayos tendrán un carácter de comprobación y sus resultados serán analizados en forma comparativa con los resultados obtenidos de los sistemas tradicionales.

Los sistemas propuestos a ensayar, serán realizados bajo los siguientes criterios:

a. Verificación del comportamiento de los sistemas tradicionales.

b. Análisis del comportamiento de propuestas que mejoren los sistemas tradicionales.

c. Adaptación de sistemas internacionales a las condiciones locales.

1. Denominación EEA1

Ensayos de sistema de arriostre de los pilotes con la viga de cimentación:

Análisis de la unión de un pilote y una viga de cimentación.

2. Objetivo

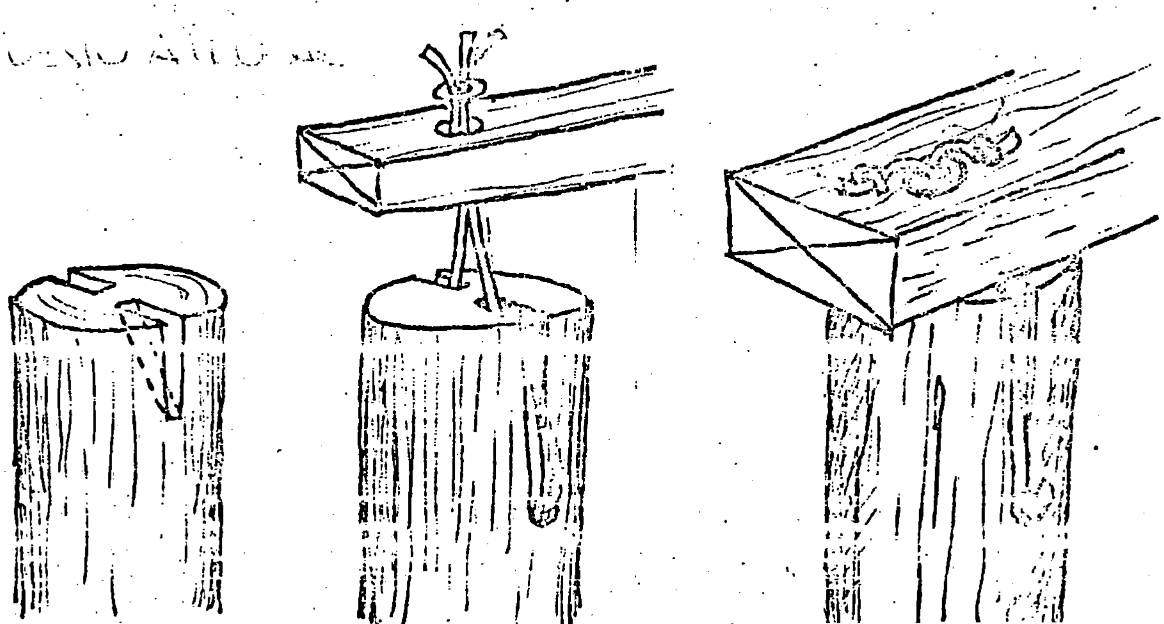
Uno de los problemas que se presentan en la cimentación de la construcción de viviendas de madera en zonas tropicales es el de la unión de los pilotes con las vigas de cimentación. Esta unión tiene que resolver no solo la estabilidad de la construcción bajo la acción de las cargas verticales, sino también la acción de las cargas horizontales como las cargas debidas a las fuerzas que van hacia arriba.

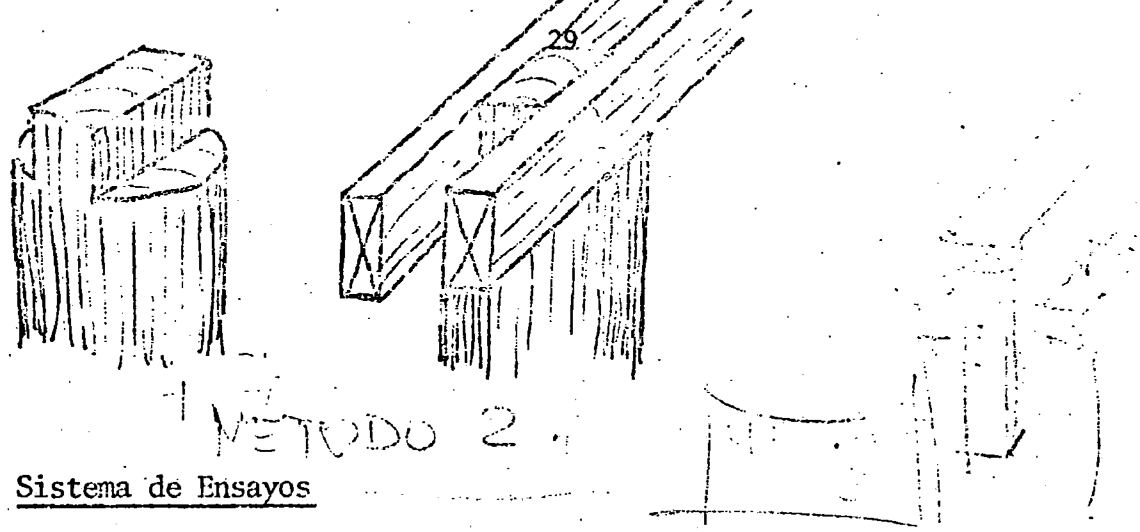
3. Metodología de Ensayos

A determinarse

4. Descripción

Se considera necesario el ensayo de un sistema que mejore sensiblemente la solución tradicional de la unión entre el pilote y la viga de cimentación. Hemos considerado conveniente la necesidad de analizar un ensayo estático que demuestre la eficiencia de la solución propuesta.





5. Sistema de Ensayos

Sistema Estático.- Encontrar la resistencia de una unión entre una viga de cimentación y su correspondiente pilote bajo la acción de las cargas verticales hacia arriba y hacia abajo, y horizontales. Estos ensayos se realizarán bajo cargas estáticas, mediante gatas dispuestas convenientemente.

6. Número de Ensayos

Las soluciones propuestas son tres. De cada una se realizarán ensayos estáticos.

Número de pruebas a determinar	3 de cada uno

7. Lugar

Laboratorio del Proyecto PADT-REFORT

8. Duración Probable de Ensayos

Preparación de Prototipos	2 semanas
Realización de los ensayos	2 semanas
Análisis de resultados	1 semana

9. Cronograma General

A determinarse.

1. Denominación EEA2

Cálculo de máximo espaciamiento de anclaje de una solera en la cimentación corrida de concreto simple.

2. Objetivo

Ensayar la capacidad resistente a la tracción y el corte de los anclajes.

3. Metodología de Ensayos

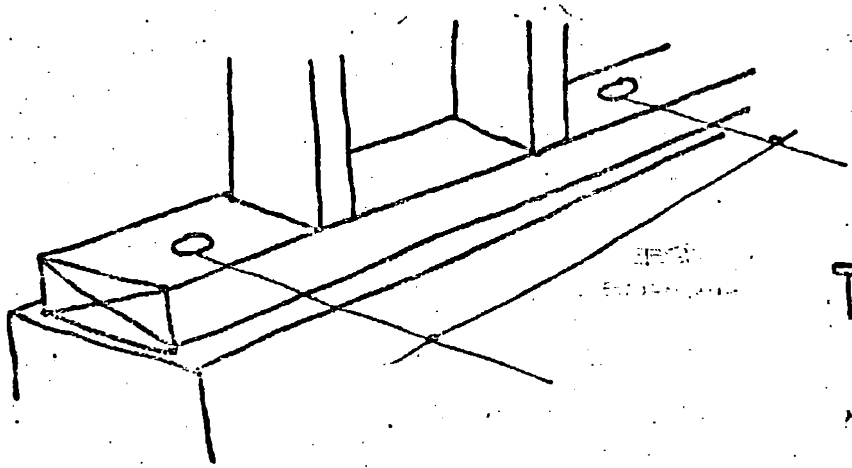
A determinarse

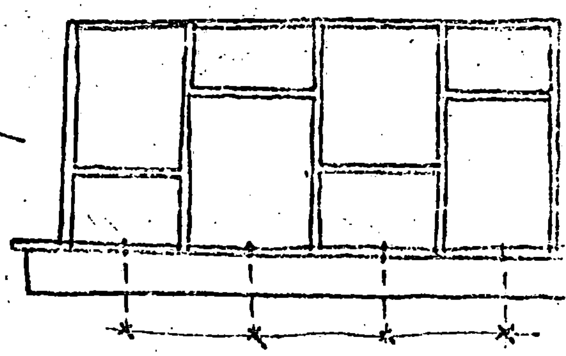
4. Descripción

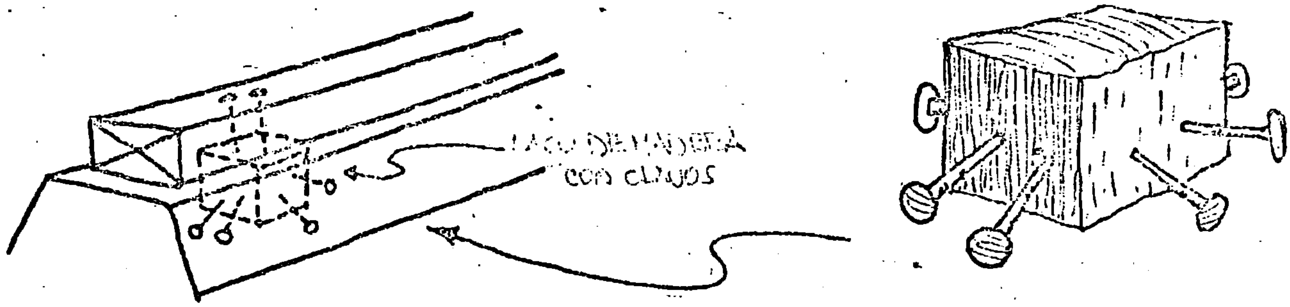
De acuerdo a las recomendaciones de los manuales correspondientes a la madera blanda, se experimentará con las maderas tropicales para verificar su eficiencia y aumentar el valor del máximo espaciamiento. Así como se analizará el comportamiento de sistemas de anclaje utilizando tacos de madera con clavos incorporados y sumergidos dentro de concreto simple de la cimentación corrida.

B) CASO DE UNION:

ESPACIAMIENTO [illegible] ANCLAJES DE [illegible]







5. Sistema de Ensayo

Sistema de Ensayos estáticos

6. Número de Ensayos

Las soluciones propuestas son dos: se considerará la conveniencia de ensayar dos prototipos de cada solución propuesta.

Total de pruebas	a determinarse

7. Lugar

Laboratorio del Proyecto PADT-REFORT

8. Duración probable de ensayos

Preparación de prototipos	4 semanas
Realización del ensayo	1 semana
Análisis de los resultados	1 semana

9. Cronograma General

A determinarse

1. Denominación EDB1

Ensayo de un muro compuesto de bastidor de madera con albañilería incorporada.

2. Objetivo

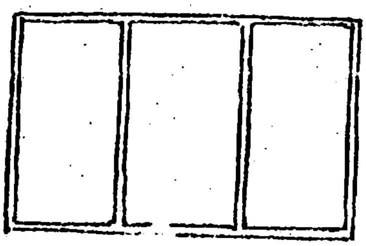
Se trata de analizar el comportamiento de un muro de marcos de madera con albañilería incorporada y verificar las mejoras propuestas en el diseño tradicional de dicho sistema.

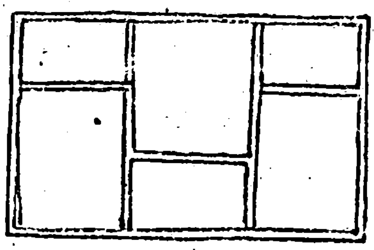
3. Metodología de Ensayos

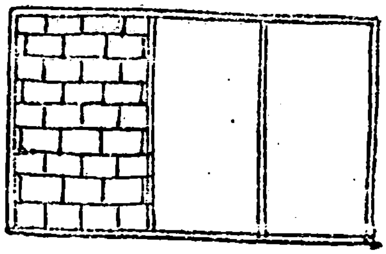
Como primera aproximación se diseñarán dos prototipos de marcos con tramas diferentes sin albañilería, luego un muro de albañilería sin la armadura de madera. Finalmente se ensayarán dos prototipos de muros de albañilería con entramado de madera.

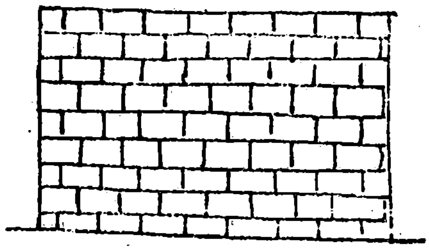
4. Descripción

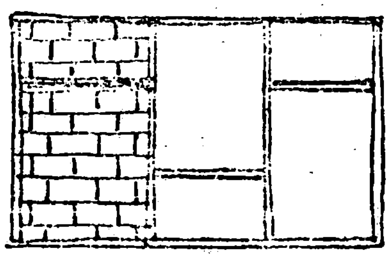
En estos ensayos se establecerá el comportamiento de un muro compuesto de madera con ladrillos. En el podremos tener valores que nos determinen la influencia de las propuestas de mejoramiento en el sistema constructivo tradicional de entramado de madera con ladrillos analizando la importancia del estucado en una cara con malla para evitar fisuramientos en los muros.





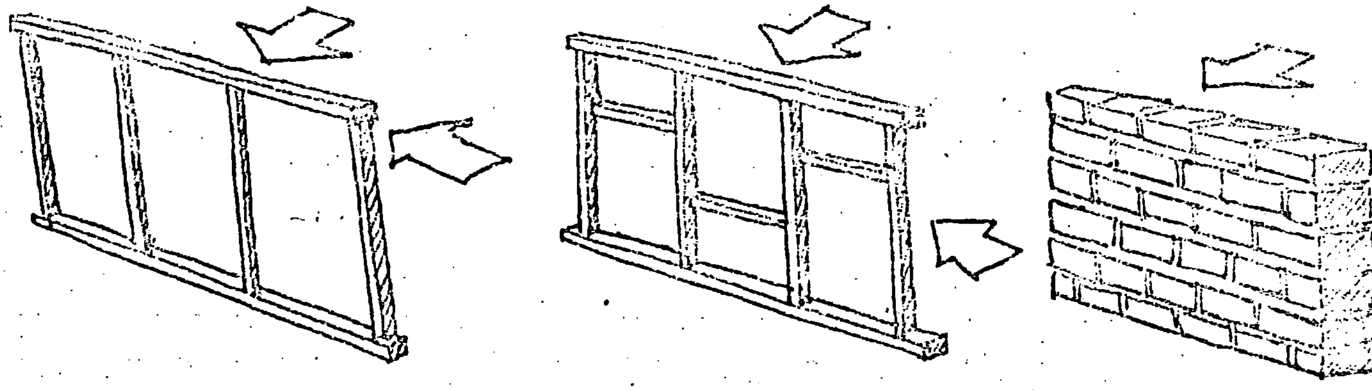


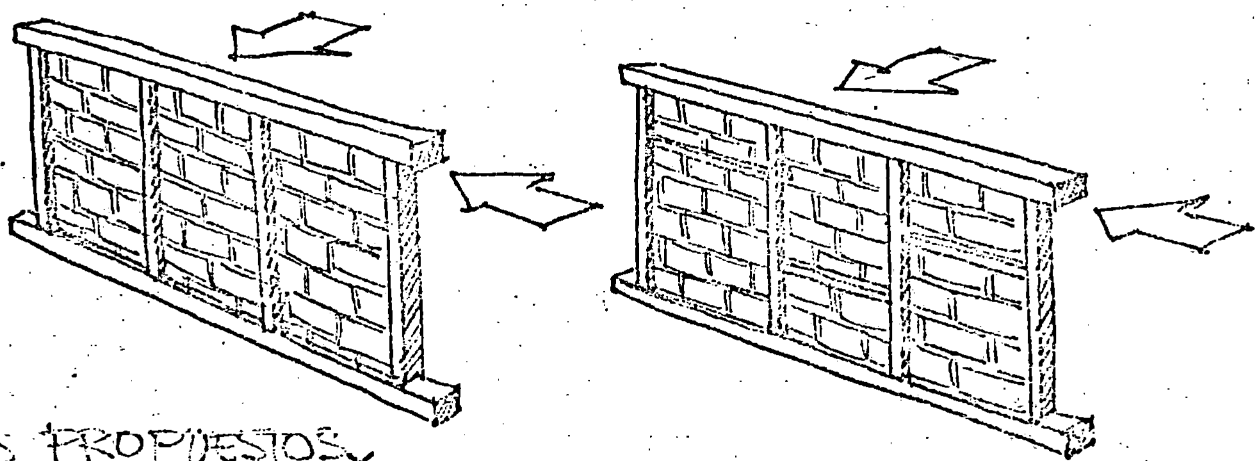




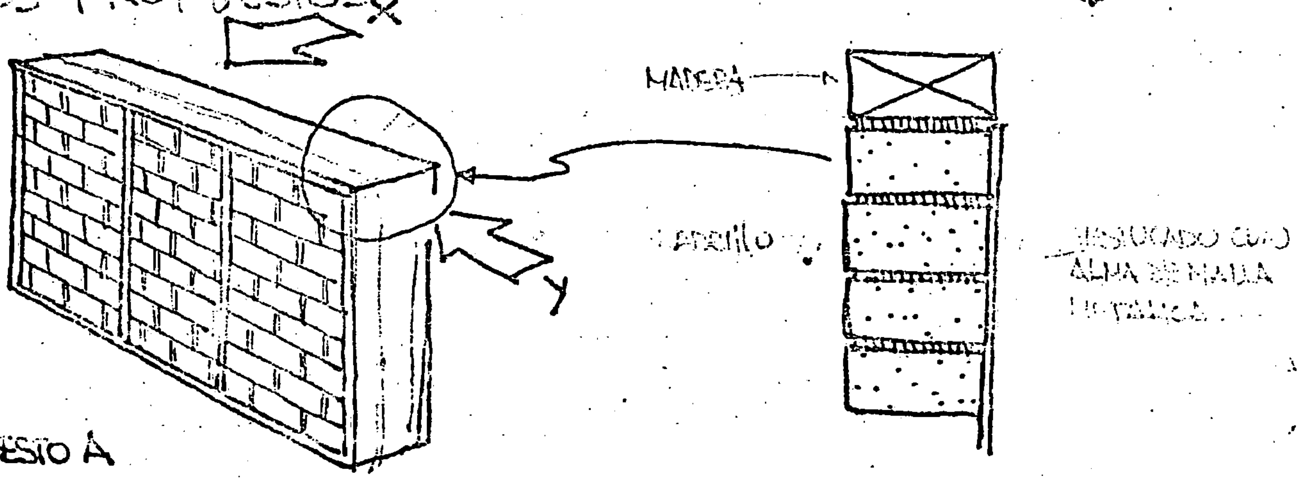
ENSAYOS

MUROS CONOCIDOS

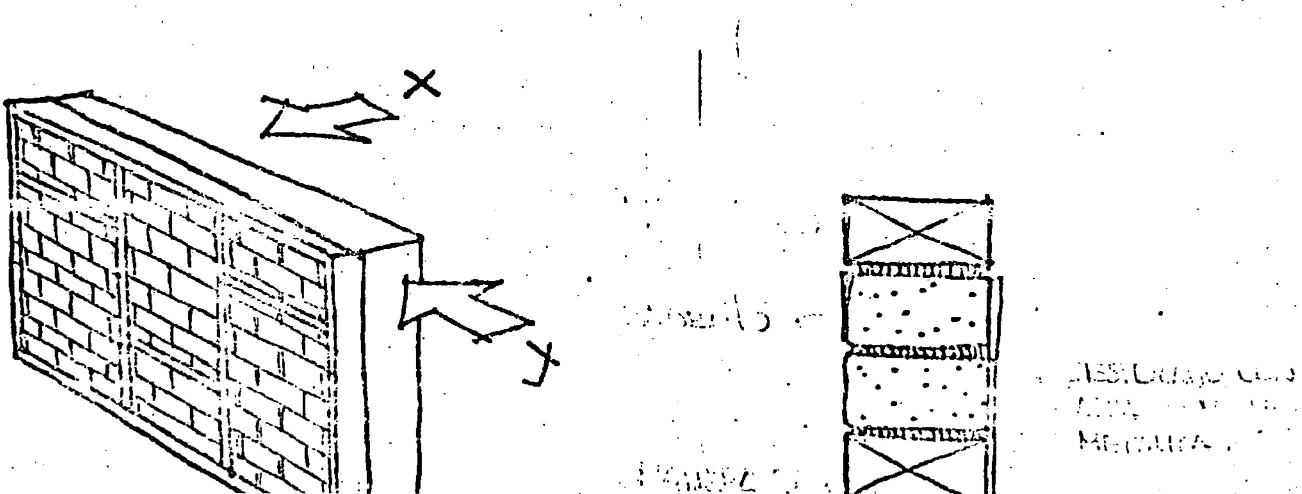




METODOS PROPUESTOS



MURO COMPUESTO A



5. Sistema de Ensayo

El prototipo será sometido a la acción dinámica con un movimiento horizontal paralelo a su superficie y otro ensayo con movimiento horizontal con una dirección perpendicular a su superficie. Los detalles de este ensayo están en proceso de determinar.

6. Número de Ensayos

1 Ensayo de marcos tipo "A"

1 Ensayo de marcos tipo "B"

1 Ensayo de muros de ladrillos sin entramado de madera

1 Ensayo de muros compuesto con ladrillos, compuesto con entramado tipo A, y

1 Ensayo de muros con entramado tipo "B"

Total de Ensayos a determinarse

7. Lugar

Laboratorio del Proyecto PADT-REFORT

8. Duración probable de ensayos

Preparación de prototipos	3 semanas
5 Ensayos de marcos	2 semanas
Ensayos de los paneles de madera	1 semana
Ensayos de los muros de ladrillo	1 mes

9. Cronograma General

A determinarse.

1. Denominación EEB2

Análisis del comportamiento de una unión bajo la acción de una cupla.

2. Objetivo

El ensayo tiene como objetivo analizar el comportamiento de una unión bajo la acción de un par de momentos. Esta unión está constituída por elementos perpendiculares en los cuales han variado las condiciones de ensamble.

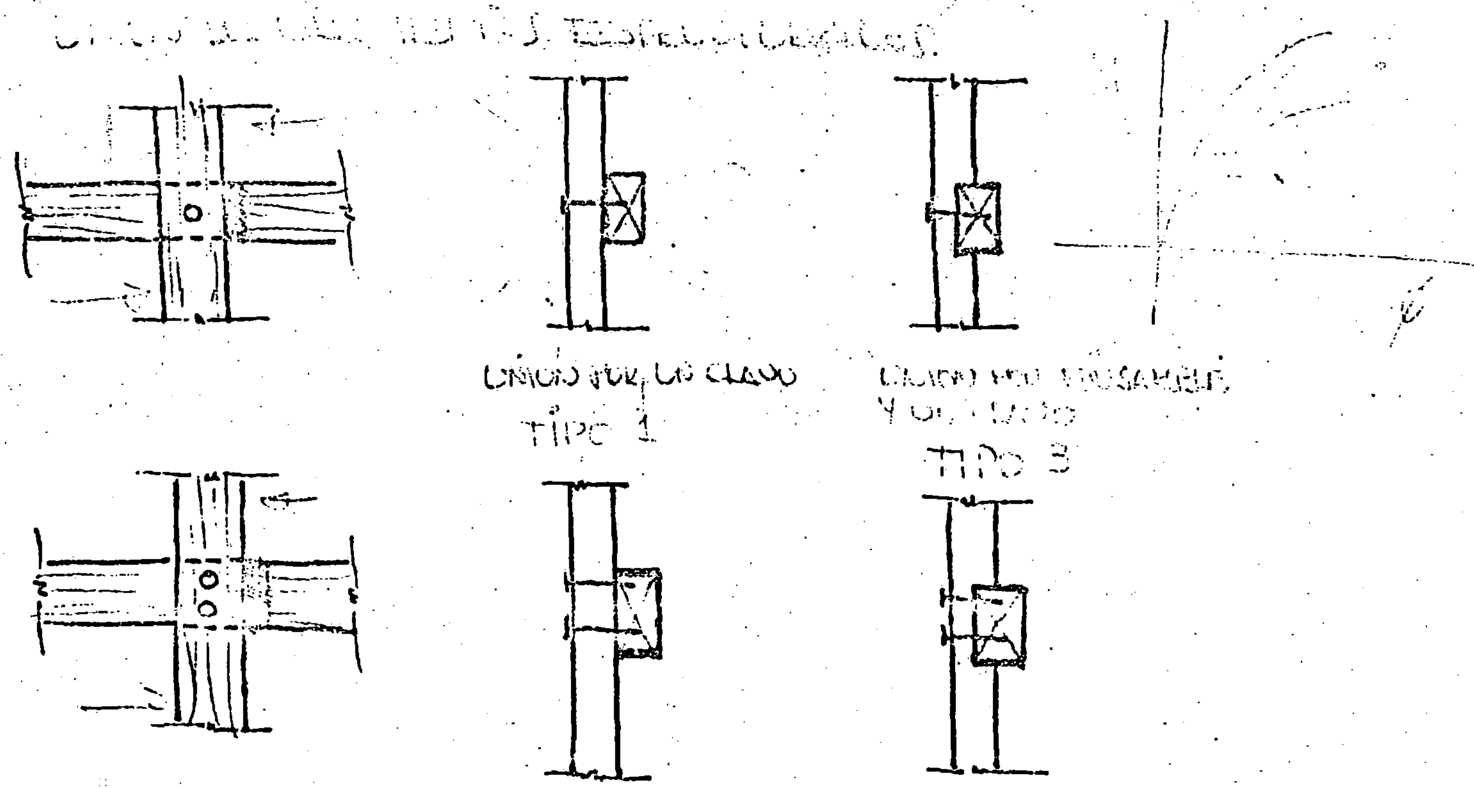
3. Metodología de Ensayos

A determinarse

4. Descripción

Este ensayo consistirá en la aplicación de una cupla en uniones de elementos perpendiculares en los cuales se variarán las condiciones de unión de este, y el número de clavos y el ensamble.

CASO DE UNIONES :

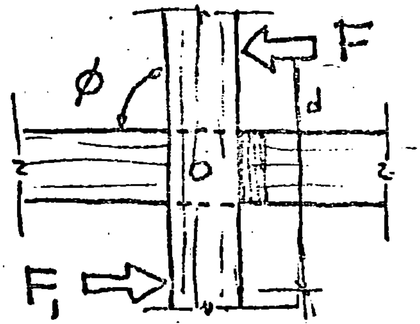


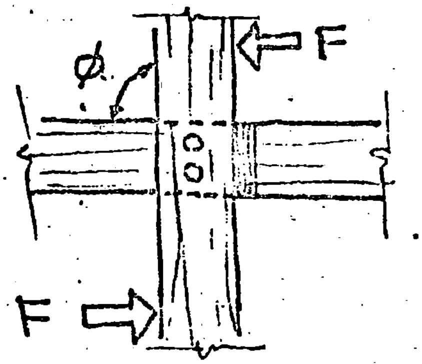
UNION POR UN CLAVO
TIPO 1

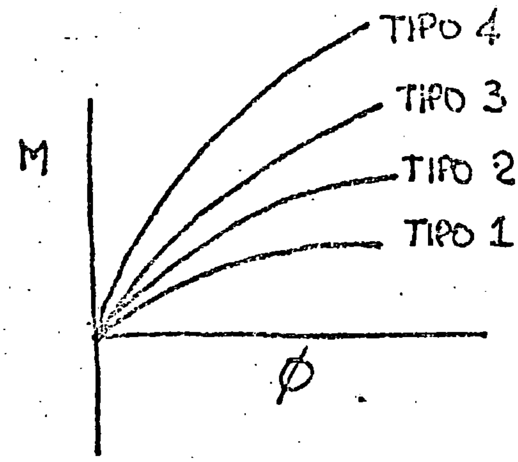
TIPO 3

TIPO 2

ENSAYOS







DETERMINACION DE DEFORMACION POR ACCION DE LA CUPLA GENERADA POR F y F'.

5. Sistema de Ensayo

Sistema estático

6. Número de Ensayos

2 prototipos de cada solución

Total de pruebas 12

7. Lugar

Laboratorio del Proyecto PADT-REFORT

8. Duración probable de ensayos

Una semana

9. Cronograma General

A determinarse

1. Denominación EEC1

Ensayo de columnas de madera para muros portantes de bastidores.

2. Objetivo

Como una manera de realizar las posibilidades de reducir las secciones en las columnas con las maderas tropicales que ensayamos, se ha considerado ensayar columnas de dimensiones calculadas de acuerdo a la capacidad resistente de la madera y coincidiendo con dimensiones que han sido utilizadas en construcciones aisladas. En este caso, se cumplirán los criterios de diseño apropiados, la influencia de los elementos de cerramiento en el comportamiento estructural.

3. Metodología de Ensayos

A determinarse

4. Descripción

Se ensayarán los siguientes casos:

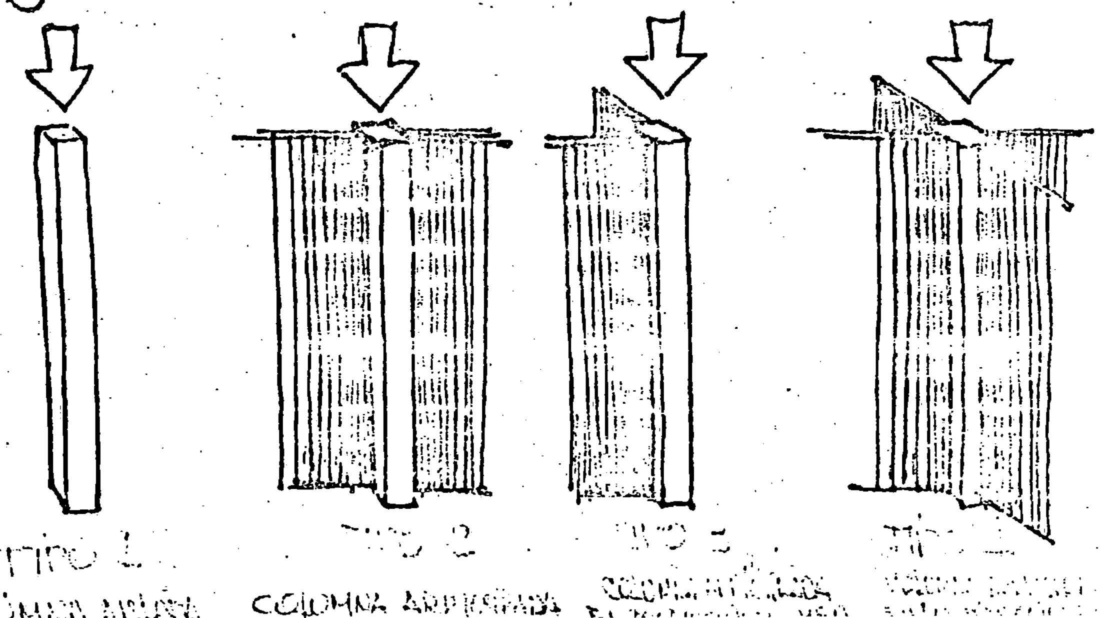
a. Una columna aislada

b. Una columna con dos paneles adyacentes

c. Una columna en esquina con dos paneles perpendiculares

d. Una columna interna con paneles en sus cuatro caras correspondientes.

ENSAYO



5. Sistema de Ensayos

   Estático

6. Número de Ensayos

   18

7. Lugar

   Laboratorio del proyecto PADT-REFORT

8. Duración probable del ensayo

Preparación de probetas		2 semanas
Ejecución del ensayo y análisis de resultados		3 semanas
Desarrollo teórico	4	~~2~~ semanas

9. Cronograma General

   A definirse

1. Denominación EED1

Ensayos de columnas compuestas

2. Objetivo

Es necesario verificar el comportamiento de las columnas conformadas por elementos muy esbeltos y con separadores intermedios. Así como comprobar los criterios de cálculos asumidos.

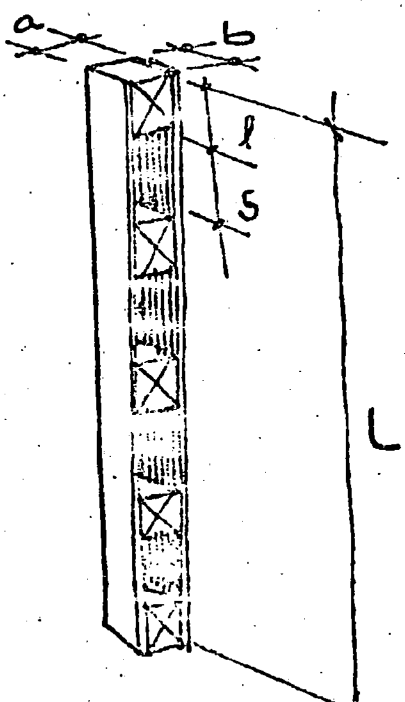
3. Metodología de Ensayos

A determinarse.

4. Descripción

En vista de que las características mecánicas de las maderas tropicales nos posibilitan reducir las dimensiones de las secciones de los componentes de una viga compuesta, debemos verificar el comportamiento estructural de este elemento por razones de comprobación de comportamiento con respecto a la esbeltez de la columna compuesta, la esbeltez de los tramos entre los separadores y el comportamiento de los sistemas de unión de los extremos.

ENSAYOS



COLUMNA COMPUESTA SOMETIDA A CARGAS VERTICALES [illegible]

[illegible]
[illegible] (l)
ESPACIAMIENTO DE SEPARADORES (S)
COMPORTAMIENTO DE LOS SISTEMAS DE UNION EN LOS EXTREMOS.

5. Sistema de Ensayos

   Estático

6. Número de Ensayos

   A determinarse

7. Lugar

   Laboratorio del proyecto PADT-REFORT

8. Duración probable del ensayo

Preparación de probetas	2 semanas
Ejecución de los ensayos	2 semanas
Análisis de resultados	1 semana

9. Cronograma General

   A determinarse.

1. Denominación EED2

Ensayo de una unión entre un tijeral y un muro en una construcción tradicional.

2. Objetivo

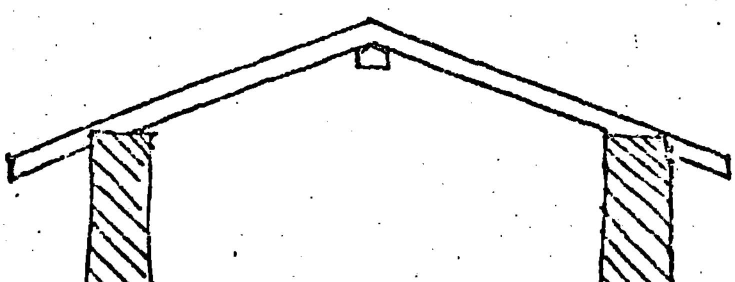
Entre las soluciones tradicionales de tijerales apoyados sobre muros de adobe, existen algunas que son usadas con mucha frecuencia y que necesitan un análisis de su comportamiento. En el ensayo se propone un sistema que mejorará las condiciones estructurales anteriormente mencionadas. Esta sugerencia será sometida a ensayo comparativo con respecto a la solución tradicional.

3. Metodología de Ensayos

A definirse.

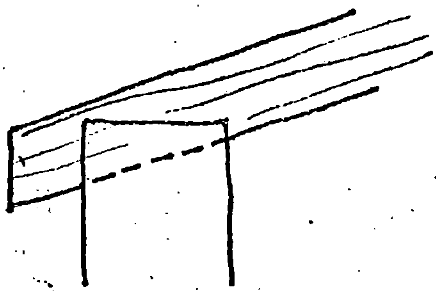
4. Descripción

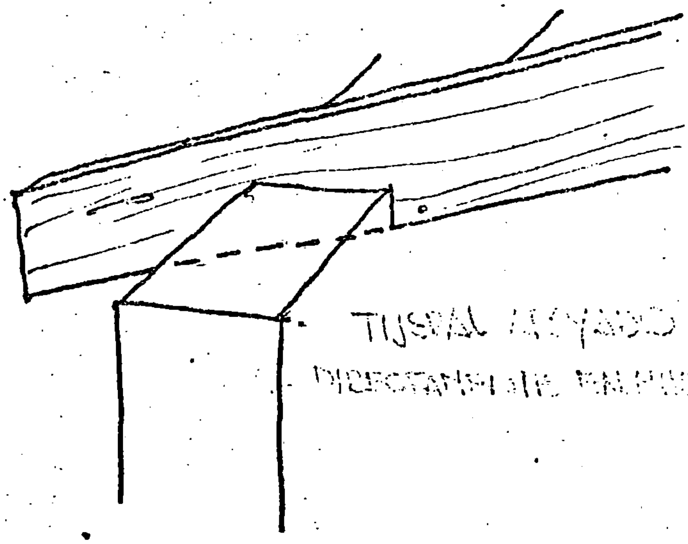
Se repetirán las condiciones que se presentan en la construcción tradicional en los puntos de apoyo de los muros de adobe y los tijerales. Las soluciones propuestas analizarán el comportamiento del anclaje de la viga solera y el muro de adobe. Se observará la relación, deficiencia entre el sistema de solera tradicional y un sistema tipo camiseta de madera.



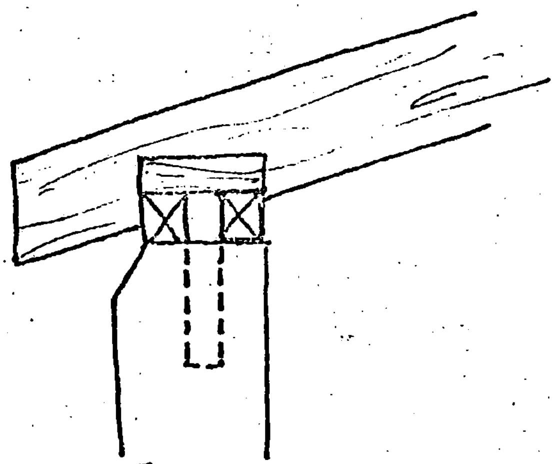
ENSAYOS

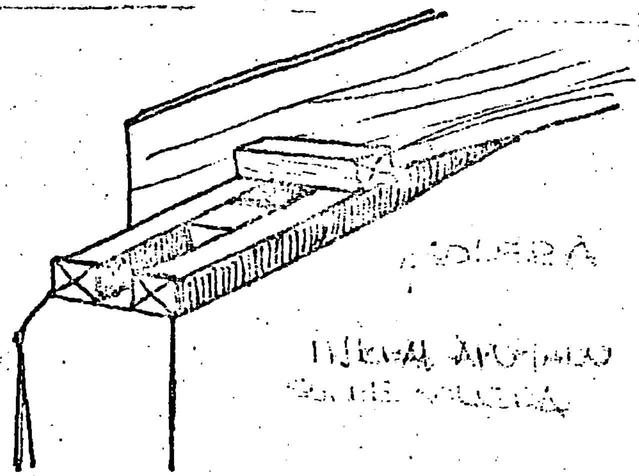
MÉTODOS CONOCIDOS





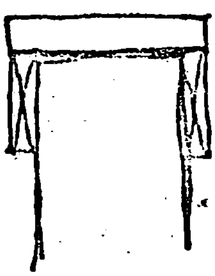
MÉTODO 1

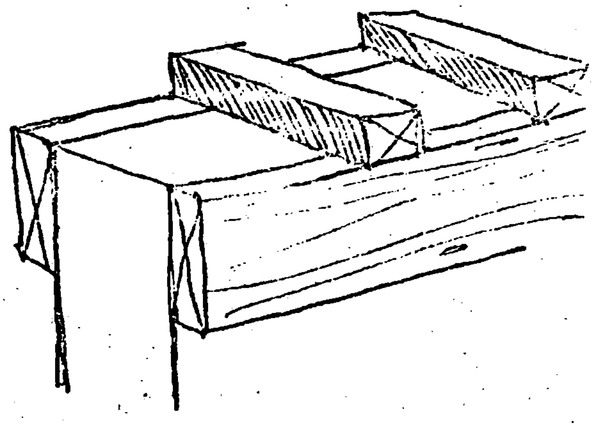




MÉTODO 2

MÉTODOS [illegible]





MÉTODO 1

1. <u>Denominación</u>

Ensayo del comportamiento de un módulo estructural con muros de altura reducida y entramado de madera.

2. <u>Objetivo</u>

Con el objeto de disminuir el peligro de falla estructural en los muros de adobe debido a la altura de estos, se ha considerado conveniente reducir la altura del muro, disminuyendo por consiguiente su esbeltez y agregarle, para conseguir la altura apropiada, un entramado de madera. Esta propuesta necesita un ensayo de comprobación que determine la forma de comportamiento de la unión entre el entramado y el muro, y la unión entre el entramado y la estructura de techo.

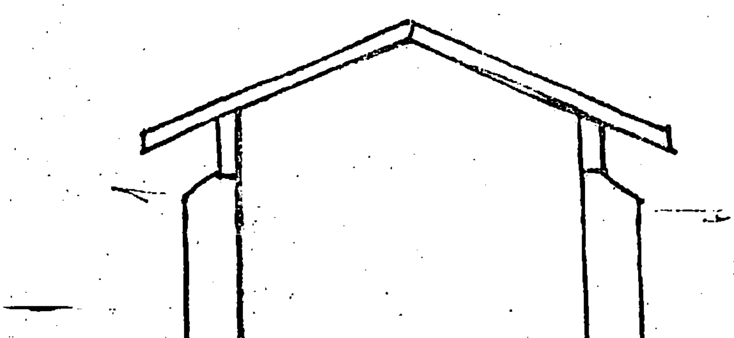
3. <u>Metodología de Ensayos</u>

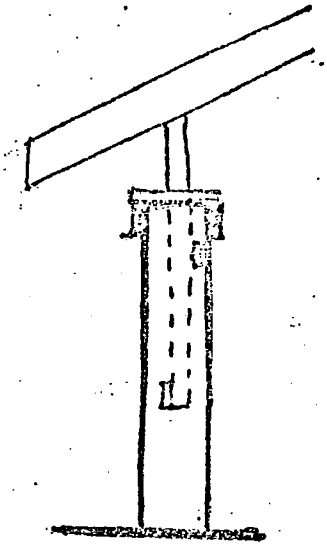
A determinarse.

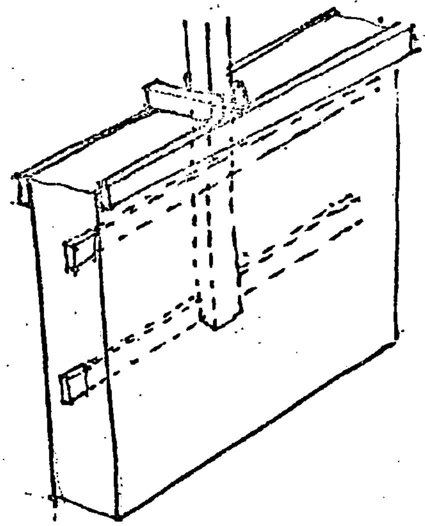
4. <u>Descripción</u>

Se considerará un prototipo a dimensiones naturales de acuerdo a dimensiones apropiadas de dimensiones significativas a las usadas comunmente. Sobre esta base de albañilería de adobe se construirá el entramado adicional de madera, y sobre ello, la estructura de techo.

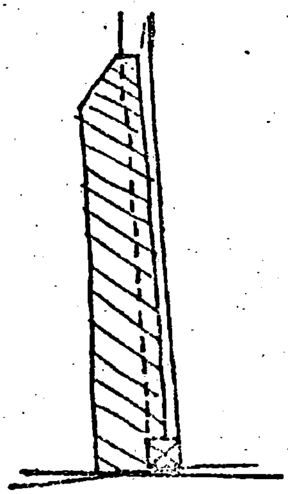
CASO DE MODULO ESTRUCTURAL

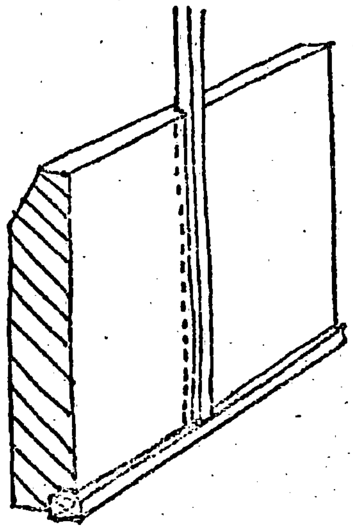






METODO 1





METODO 2

5. <u>Sistema de Ensayos</u>

Dinámico

6. <u>Número de Ensayos</u>

1

7. Lugar

Laboratorio del proyecto PADT-REFORT

8. Duración probable del ensayo

2 meses

9. Cronograma General

A determinarse.

1. <u>Denominación</u> EDM2

Análisis de una estructura de tijeral.

2. <u>Objetivo</u>

Se verificará a escala 1 en 1 las características de comportamiento de una estructura de tijeral comúnmente construída en forma tradicional en comparación con uno modificado. Las modificaciones serán centradas a nivel de uniones y secciones de los elementos, así como la subdivisión de estos.

3. <u>Metodología de Ensayos</u>

A determinarse

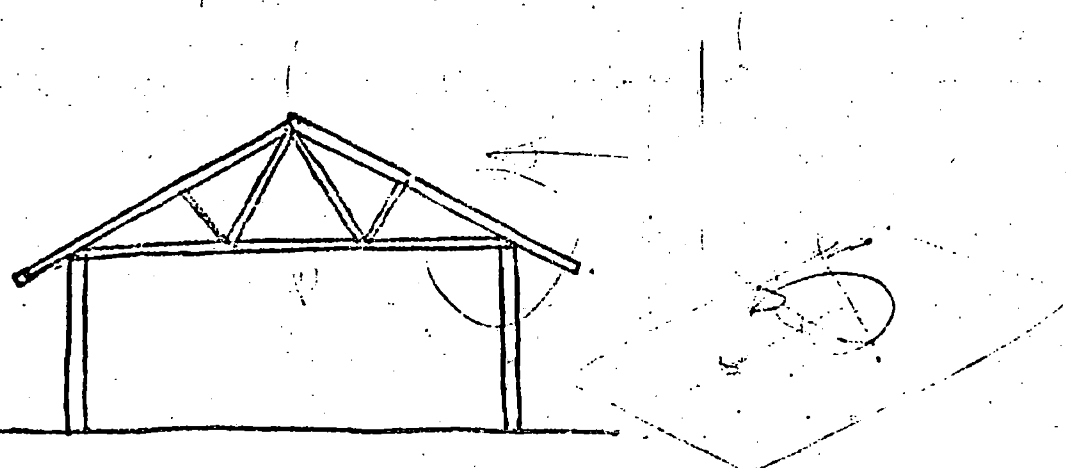
4. <u>Descripción</u>

El presente ensayo tendrá varias etapas:

- El ensayo de la capacidad resistente del tijeral aislado
- El ensayo de la capacidad resistente del tijeral con las columnas incorporadas.
- El ensayo de la capacidad resistente con un muro de albañilería.
- Estudio de la estabilidad de un conjunto de tijerales.

CASO DE MUELLES

APOYO DE TIJERALES A COLUMNAS



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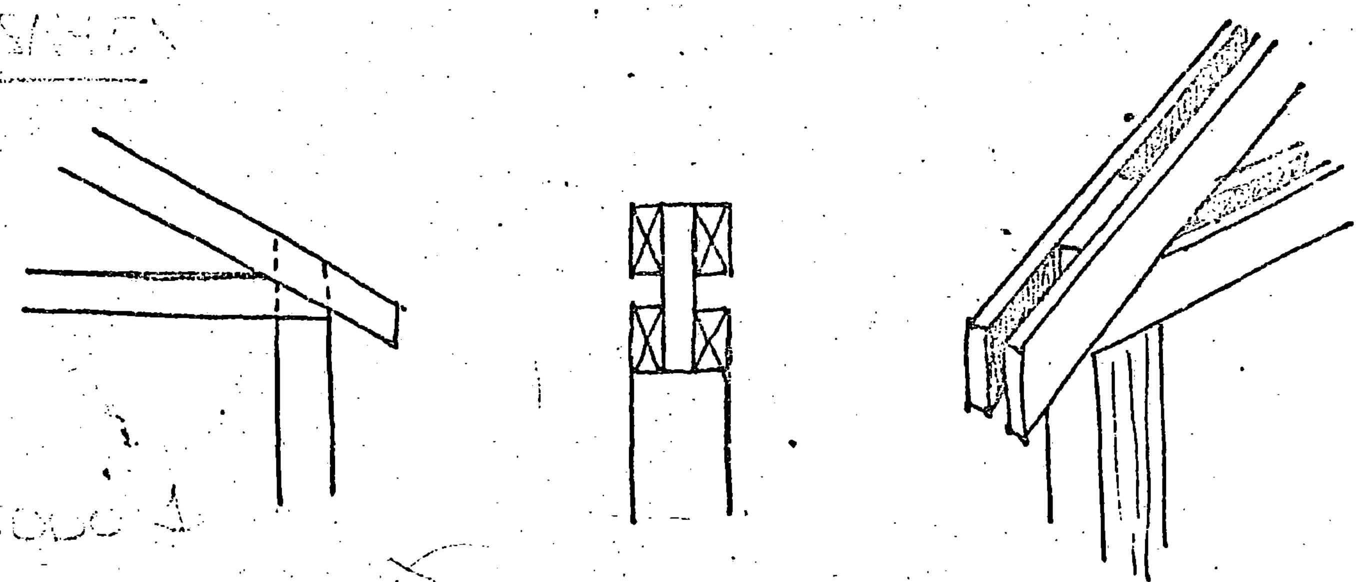
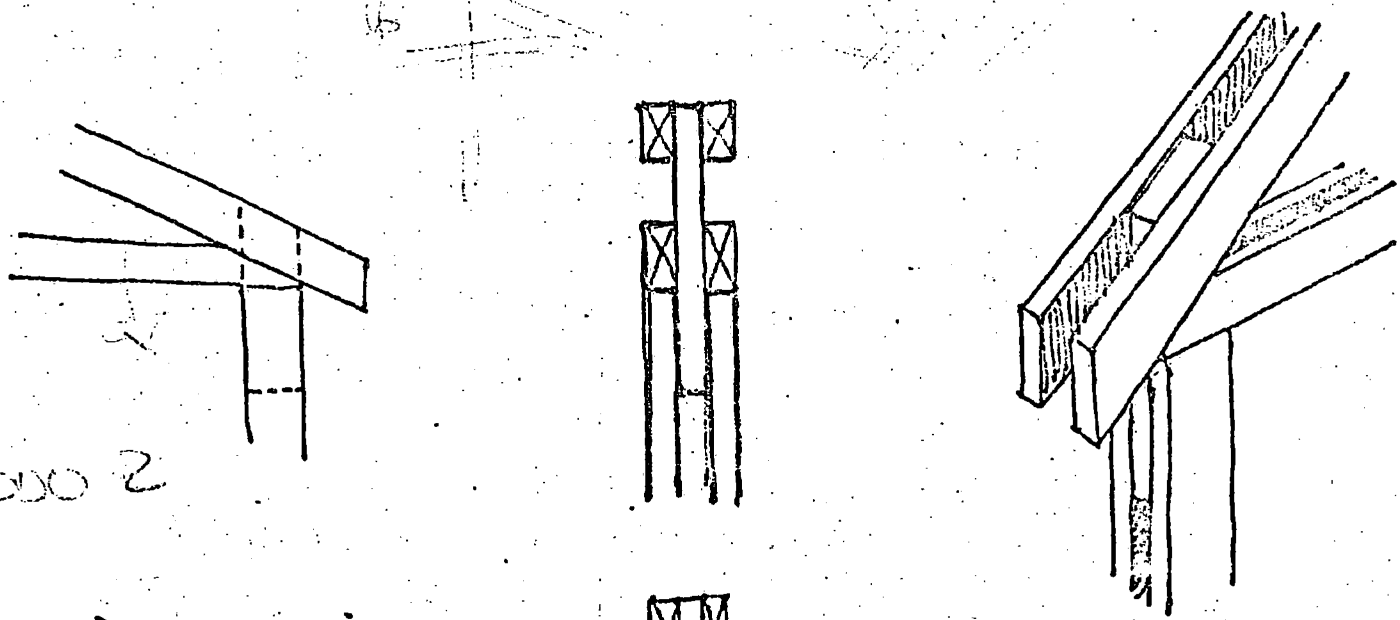
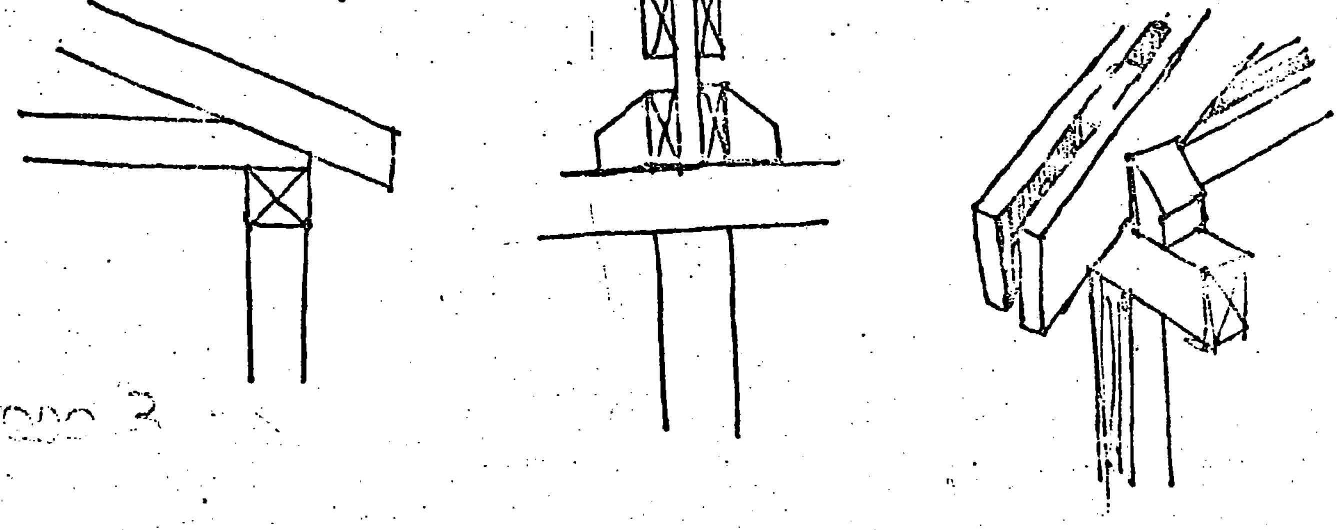


METODO 1



METODO 2



METODO 3

5. Sistema de Ensayos

   Estáticos

6. Número de Ensayos

   A determinarse

7. Lugar

   Laboratorio del proyecto PADT-REFORT

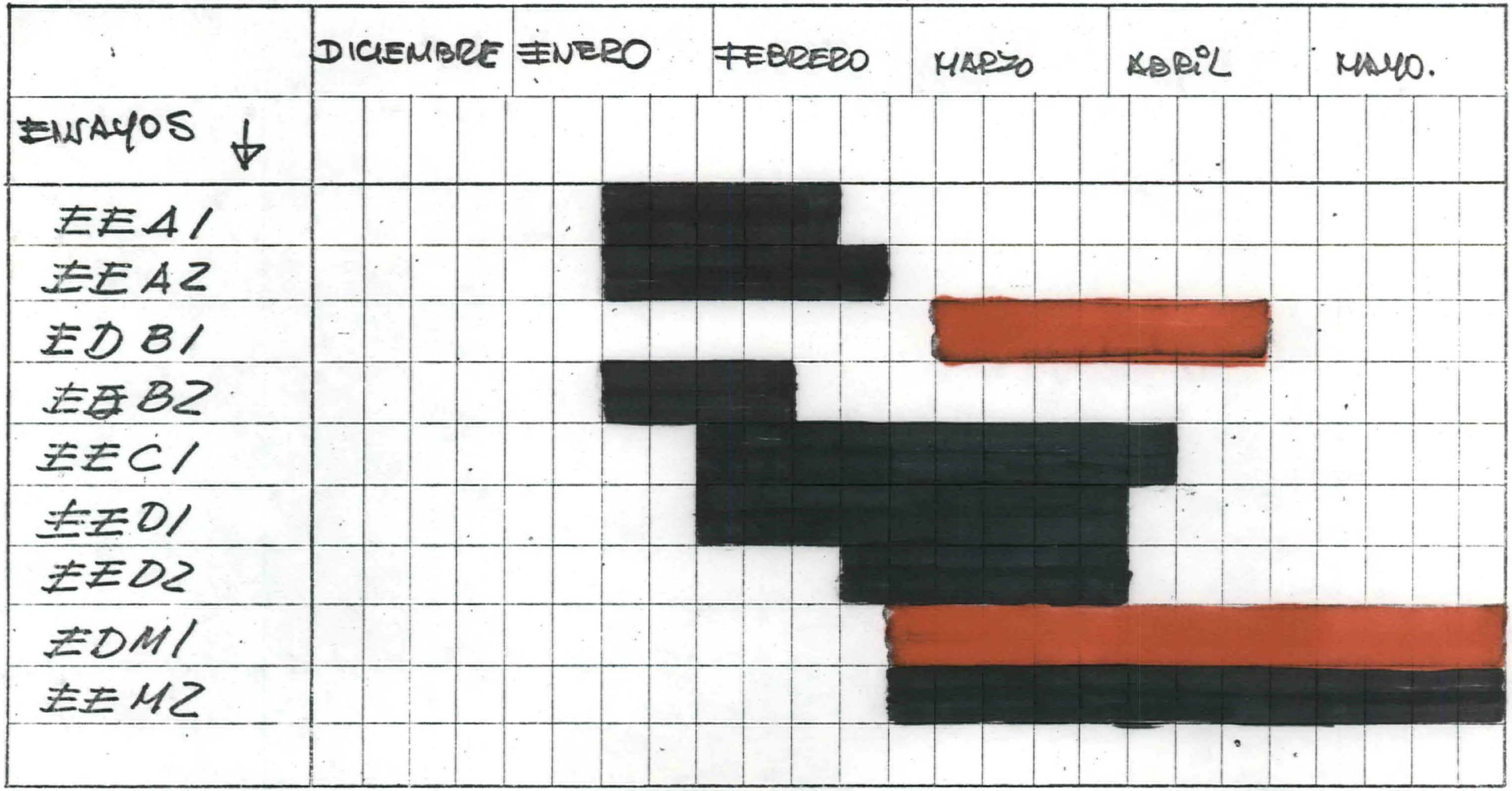
8. Duración probable del ensayo

   2 meses

9. Cronograma General

   A determinarse.

RM/lr


DICIEMBRE
ENERO
FEBRERO
MARZO
ABRIL
MAYO.
ENSAYOS
EEA1
EEA2
EDB1
EEB2
EEC1
EED1
EED2
EDM1
EEM2

APPENDIX E

EQUIPO PARA ENSAYOS DINAMICOS DE PROTOTIPOS DE CASAS DE MADERA

Los sistemas y partes principales del equipo propuesto son (ver figura N° 1):

1. Mesa vibradora
2. Unidad motriz de la mesa vibradora
3. Apoyos, cimentación y anclaje de la mesa y unidad motriz
4. Mandos y controles de la unidad motriz, y
5. medidores y registro de las reacciones del especimen (prototipo)

1. MESA VIBRADORA

Dimensiones: 4.8 x 4.8 m.

Peso: aprox. 2 ton

Material: plancha y perfiles de acero soldados en estructura celular.

Costo aproximado: US$ 3000

Plazo de entrega: 60 días a partir de la orden de fabricación

Fué diseñada por los especialistas del PADT-REFORT y será íntegramente fabricada en el Perú. No se contempla la compra o importación de materiales distintos a los corrientemente disponiblesen el mercado nacional.

Estado actual del proyecto: Se ha concluido el diseño y elegido el fabricante. La tecnología de fabricación es materia de consulta y discusión actual (entre el fabricante y los especialistas del PADT-REFORT)

2. UNIDAD MOTRIZ DE LA MESA VIBRADORA

Sería comprada a fabricantes extranjeros y fué elegida por recomendación de los especialistas del PADT-REFORT, en consulta con los fabricantes.

A la fecha existen dos alternativas de compra:

2.1 Motor eléctrico

Costo aproximado: 15000 US$ (incluído sus mandos, control y y variador de velocidad)

Plazo de entrega: 16 semanas a partir de la orden de compra

Estado actual de la negociación: Verificación, por los especialistas del proyecto, de las concordancias entre nuestras necesidades y las características técnicas de los motores hasta hoy ofertados.

2.2. Motor hidraúlico

Costo aproximado: US$ 33000 (incluidos sus mandos y control)

Plazo de entrega: 16 semanas a partir de la orden de compra.

Evtado actual de la negociación: Consulta técnica con los fabricantes sobre el tipo y características de la unidad más adecuada a nuestros objetivos y necesidades.

3. APOYOS, CIMENTACION Y ANCLAJE DE LA MESA Y UNIDAD MOTRIZ

Fueron diseñados por los especialistas del PADT-REFORT. No requieren de la compra o importación de materiales diferentes a los corrientemente disponibles en el mercado peruano.

Costo global: 6000 US$

Plazo de ejecución: 30 días

Estado actual del proyecto: Diseño a concluirse una vez elegida la unidad motriz.

4. MANDOS Y CONTROLES DE LA UNIDAD MOTRIZ

Consideradas las alternativas de unidad motriz, los mandos y controles serían fabricados o comprados de acuerdo al siguiente detalle:

4.1. Mandos y controles para el motor eléctrico

Se comprarían de fabricantes extranjeros los mandos del motor (incluidos en el precio de éste) y el variador y control de velocidad del mismo. Los generadores y el control de desplazamiento de la mesa serían fabricados en el Perú*.

Costo Aproximado: El de los mandos del motor y el variador y control de velocidad se indica incluído en el precio del motor. Los mecanismos de generación, variación y control del desplazamiento (bielas y excéntricas) costaría parox. 3000 US$.

Plazo de entrega: mandos del motor y variador: junto con el motor
generador y control de desplazamiento: 60 días a partir de la orden de fabricación.

Estado actual de la negociación y proyecto:

(a) controles del motor: análisis técnico de las ofertadas con cada motor.

(b) generador y control de desplazmiento de la mesa: diseño terminado y fabricante elegido. Consultas ~~mutuas~~ mutuas sobre tecnología de fabricación y selección de materiales (Se ha fabricado un prototipo del mecanismo y probado sus características cinemáticas)

4.2. Mandos y controles para unidad motriz hidraúlica.

Se comprarían del proveedor de la unidad motriz.

Costo aproximado: Incluido en el mencionado para la unidad motriz.

Plazo de entrega: Junto con la unidad motriz.

Estado actual de la negociación: consulta técnica y comercial sobre la posibilidad de comprar los mandos y controles más elementales e indispensables para el funcionamiento del sistema. No se considera necesario,

---

* El mecanismo de generación y control del desplazamiento se compone de excéntricas variables y bielas que convierten la rotación del eje del motor en desplazamiento ajustable de la mesa.

4.

en esta etapa del proyecto, comprar sistemas de mando y control programado o complejo.

5. MEDIDORES Y REGISTRO DE LAS REACCIONES DEL ESPECIMEN

Se ha desarrollado y diseñado con sistema de medición y registro del desplazamiento, velocidad y aceleración de uno o más puntos del prototipo ensayado. Todo el sistema, excepto el registrador, es de fabricación nacional.

Costo aproximado: para medición de 10 puntos alrededor de 1400 US$*
El registrador, dependiendo de su capacidad, puede llegar a costar 4000 y más de US$.

Plazo de entrega: 30 días a partir de la orden de fabricación.

Estado actual del proyecto: Diseño concluido, prototipos probados, sensores y aparatura eléctrica en plena fabricación La compra del registrador está en proceso de análisis técnico de las ofertas.

Considerado todo esto, la única decisión importante aún pendiente en la compra de un motor eléctrico o hidraúlico -(incluídos mandos y controles). Esto afecta el aspecto presupuestario del proyecto pero no así su concepción o lineas maestras. El proyecto es único en todos sus aspectos y solo presenta alternativas en lo referente a esta compra.

SA/vd.

* El sistema de los sensosres y aparatura electrónica de medición equivale en todas sus características a similares que en el caso de Phillips, por ejemplo, cuestan más de 5000 US$.

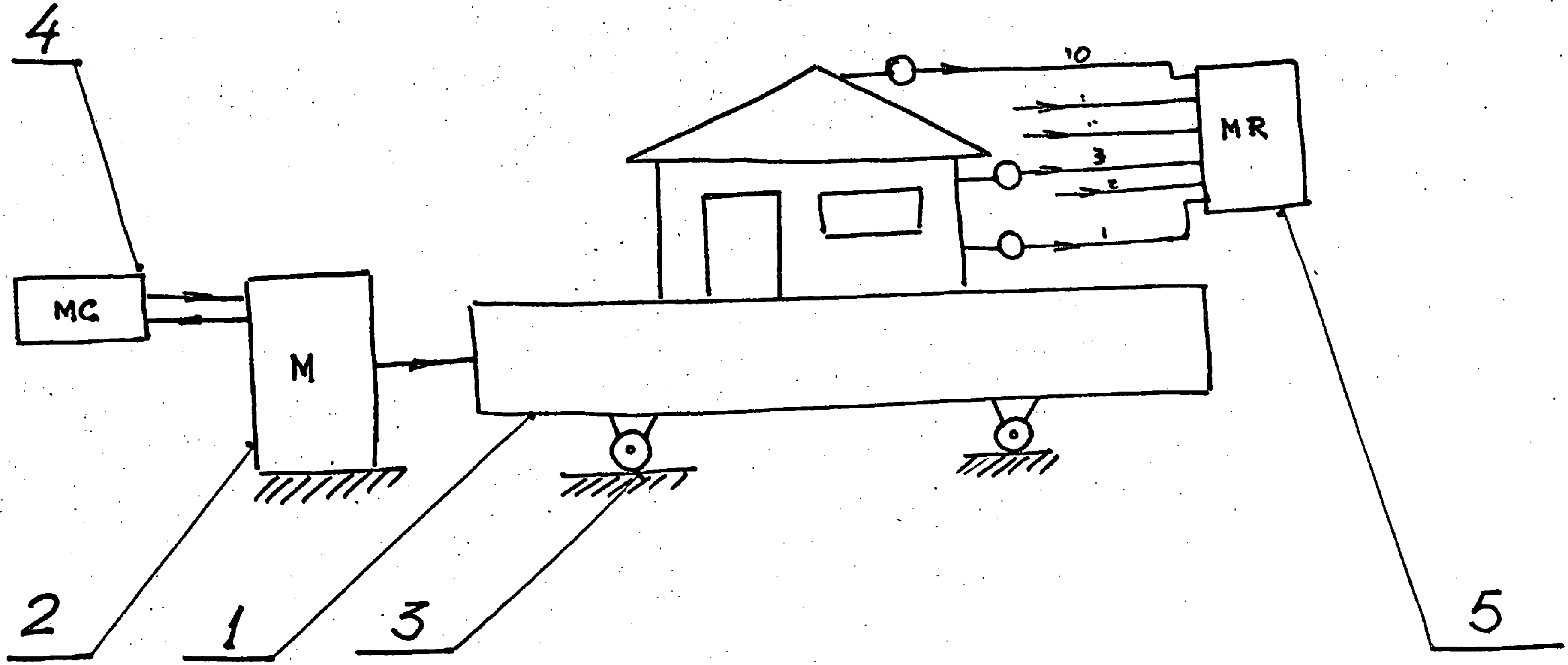


FIG. N° 1 ESQUEMA DEL EQUIPO PROPUESTO PARA ENSAYOS DINAMICOS DE PROTOTIPOS DE CASAS DE MADERA

1. Mesa
2. Unidad motriz de la mesa
3. Apoyo y cimentación de la mesa y unidad motriz
4. Mando y control de la unidad motriz
5. Medición y registro de las reacciones del especimen

APPENDIX F

RESOLUCION N° 5: PROYECTOS ANDINOS DE DESARROLLO TECNOLOGICO EN EL AREA DE RECURSOS FORESTALES TROPICALES

En base al informe de la Junta del Acuerdo de Cartagena sobre el desarrollo de los proyectos Andinos de Desarrollo tecnológico en el área de Recursos Forestales Tropicales, la Comisión I señaló la importancia de estos proyectos por los resultados prácticos que se vienen alcanzando y ha considerado prudente recomendar al Consejo Agropecuario someter a la consideración de la II Reunión de Ministros de Agricultura la siguiente Resolución:

Los Ministros de Agricultura de los Países Miembros del Acuerdo de Cartagena:

CONSIDERANDO:

Que los Proyectos Andinos de Desarrollo Tecnológico en el Area de Recursos Forestales Tropicales se han mostrado como un mecanismo operativo y concreto de integración subregional en materia de cooperación técnica, capacitación y generación de tecnologías apropiadas a la realidad de nuestros países.

Que el Proyecto "Estudio Integral de la Madera para Construcción" ha estimulado la creación y consolidación de grupos de investigación e infraestructura técnico-científica apropiada en los países participantes.

Que como resultado del mencionado Proyecto se podrá disponer de un bagaje técnico adecuado en cuanto se refiere al conocimiento técnico de la madera como material altamente competitivo en las actividades de construccion.

Que es necesario continuar las actividades de investigación de este Proyecto en una segunda fase que contemple la fabricación de sistemas constructivos y viviendas de madera que puedan aportar soluciones al problema habitacional de la Subregión.

Que para la iniciación de una segunda fase del Proyecto es necesario que los países cumplan con los plazos establecidos en el plan de operaciones de la Junta.

Resuelven:

1. Encargar a la Junta del Acuerdo de Cartagena la búsqueda y proposición de nuevos proyectos de desarrollo tecnológico para el sector forestal, que incluyan actividades de investigación referentes a conservación, manejo y utilización del recurso.

2. Reforzar y acelerar los trabajos de investigación de los países a fin de que se logre su finalización antes del mes de junio de 1977 según lo programado por la Junta.

3. Dotar a los Centros de Investigación participantes de recursos de personal y financieros que les permita incrementar su actual capacidad de producción.

4. Solicitar y colaborar con la Junta del Acuerdo de Cartagena en la búsqueda de financiamiento para que las publicaciones de los resultados del proyecto actualmente en ejecución se realicen en cantidad suficiente que permitan su distribución masiva en los países de la Subregión.

5. Solicitar a la Junta del Acuerdo de Cartagena que a breve plazo entregue a los países los términos de referencia de la segunda fase del proyecto, que contenga un detalle adecuado de objetivos, actividades y de presupuesto de gastos de contrapartida para cada país.

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REPORT No. 3

UNIVERSITY OF TORONTO

Faculty of Forestry and Landscape Architecture

Aug.'77

12 August, 1977.

Mr. J. H. Hulse,
Program Director,
Agriculture, Food and Nutrition Sciences
Division,
International Development Research Centre,
Box 8500,
Ottawa, Ontario. K1G 3H9

Dear Mr. Hulse: Re: Forestry Technology (Andean Pact) Project
Centre File 3-P-74-0009

In accordance with the terms of the IDRC Offer of Consulting Contract dated July 11, 1977, I am submitting herein a report on my visit to the Project in Lima, Peru in the period July 15-31, 1977.

In contrast to my two previous submissions on the Project, I am reporting to you at this time in letter format because you may not wish to pass along these comments (at least not in total) to the Junta for publication. The reason is that this report will paint a less enthusiastic picture of the Project than did my others.

In the most general sense, my attitude to the accomplishments of the Project to date is a combination of disappointment, chagrin, and cautious optimism for the future. The reason for each of these attitudes will become clear as I describe the progress that has been made in each of the areas that I was asked to examine.

1. The Cartilla (Manual of Wood Construction)

Progress has been made on the Cartilla since my last visit. At the beginning of this visit, Sr. Takahashi reviewed the need for this publication in the Subregion and the general objectives and organization of the Cartilla. He stressed that there is no present significant widespread experience or expertise with the use of wood in engineered construction in the Andean Pact countries and therefore a program of educating, and of generating enthusiasm for the use of wood, must play a central role in the publication.

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The Cartilla consists of 21 chapters, as follows:

1. Construcción con madera - Ejemplos
2. Antecedentes de uso de la madera
3. El bosque
4. El árbol
5. Productos a base de madera
6. Secado de la madera
7. Preservación de la madera
8. Protección contra la humedad
9. Protección contra los elementos térmicos
10. Protección contra los vientos
11. Protección contra los ruidos
12. Protección contra incendios
13. Protección contra sismos
14. Sistemas estructurales
15. Comportamiento estructural
16. Uniones estructurales
17. Instalaciones electromecánicas
18. Herramientas e instrumentos de carpintería
19. Soluciones constructivas para viviendas con madera
20. Representación gráfica
21. Glosario de términos

I have reviewed this material (as has Mr. Ilmar Teng, the architecture expert from Sweden who was visiting the Project during the same period as myself) and I have come to the conclusion that this publication is definitely not a manual for wood construction. Instead, I would describe it as an introduction to the basic principles which must be understood by designers before wood can be successfully used in engineered structures in the Subregion. In my opinion, it contains little, if any, original information. It contains neither the results of research conducted in the Project nor a creative synthesis of ideas and local experience. It is a rather good interpretation, description and artistic presentation of existing world knowledge, but it does not tell me how to design and build a wood structure of any kind. I see it as a book that a person would read once or twice during a basic educational process and, having understood this background, he would then look for a proper manual of wood construction to use from day to day in the practice of his profession, be it engineering, architecture or prefabrication. In other words, we are talking about two very different publications: an educational/promotional work and a manual of wood construction; the Cartilla as produced is the first of these two.

My disappointment (and perhaps, chagrin) stems from the fact that, on my two previous visits, I had been led to believe that the Cartilla would be a combination of these above two publications. For example, in my second report (dated January 21, 1977) I recount the information presented to me by the design team in October 1976, which clearly indicated that two of the five parts of the Cartilla "... will contain original information which has been obtained either experimentally or through a synthesis of experience and technical speculation ...". Further in the report, I say "The author spent several days with Sr. Takahashi and Sr. Machicao discussing, one by one, the large volume of new technical proposals formulated to date. It was a stimulating and enlightening experience - the work that has been done is absolutely first-rate! In many cases, the proposals were concurred with, in other cases they were modified, some new ones were developed, and some were deferred until after some test results become available. The publication of this information will make a significant contribution to the world literature on tropical construction ...".

These technical proposals are not in the Cartilla. The reason given for their absence is that they have not been proven in the laboratory and, because the laboratory program is way behind schedule (which will be discussed later), this information will not be yielded from Phase I.

I was asked to suggest what steps could be taken at this point to produce the best available result from Phase I in the limited time remaining. In responding to this, it was necessary to first review the program of publications which are still to come from the Project; five separate publications are suggested:

(i) Anatomy and Identification of Wood Species in the Andean Pact Countries
(ii) Fundamental Properties of Wood Species in the Andean Pact Countries
(iii) Introduction to the Principles of Wood Construction
(iv) Manual for the Design of Wood Structures
(v) Notes for a Course in Elementary Wood Engineering

The purpose and content of each is as follows:

(a) Anatomy and Identification of Wood Species in the Andean Pact Countries

This is the work coordinated by Ana María Sibille of work done in the five countries in studying all of the 100 species in the Project at the macroscopic and microscopic levels, and in relating the common names used in each country to the proper scientific names. This is an original work and it will have scientific and technical value. The publication will include colour plates to aid in wood identification and will also have values of density or specific gravity, again, as an aid in identification. I understand that this information is almost ready to publish.

(b) Fundamental Properties of Wood Species in the Andean Pact Countries

This publication will report the results and conclusions of the various tests carried out in the five countries. This will be a document of original research data which will be a major technical contribution. It will have permanent value and will not change as will, for example, the Design Manual described later which will require periodic updating as the technology and practice of wood construction grows. This might be produced in two volumes with the following as a possible chapter breakdown.

VOLUME I - RESEARCH RESULTS

- Introduction: History of the Project - 5 countries - 100 or more species - reference to other Project publications - personnel - purpose of this publication.

- Methods of Determination of Properties: sampling from the forest resource - preparation of test specimens - details of the test procedures.

- Density and Specific Gravity: statistical values for each species - factors affecting density (location in the tree; site).

- Drying Properties: drying rate data - shrinkage values - fibre saturation point - equilibrium moisture content - defects produced during drying.

- Natural Durability and Preservation: data on natural durability - data on ability to be treated with preservatives - conclusions and recommendations for the appropriate environment and use for individual species.

- Workability: data from workability tests - recommendations for the types of manufacturing processes which are appropriate for each species.

- Mechanical Properties: statistical data for each species and for each mechanical test - correlations to determine factors (e.g., density) effecting mechanical properties.

VOLUME II - CONCLUSIONS AND RECOMMENDATIONS

The suitability of each species for various possible uses. (This will be a difficult chapter to write and will require more time to prepare; however, the material in Volume I can be published almost immediately.)

I should expand a little bit on the "correlations" mentioned above under 'Mechanical Properties'. This is a very interesting and useful exercise which involves a computer analysis to seek correlations between all of the mechanical properties determined and those factors (particularly specific gravity) which may effect the mechanical properties. This work has been completed for the Venezuelan woods and the calculations are in progress for three other countries. This work has a number of implications for the future: for example, if specific gravity turns out to be an effective predictor of strength for all the 100 species, this means that a greatly reduced testing program is warranted for additional species. All that will be required is to determine specific gravity for the species, enabling one to predict the mechanical properties, and then to carry out only spot-checks to verify the predictions.

(c) Introduction to the Principles of Wood Construction

This is the Cartilla essentially as it now exists. It is an educational and promotional publication which will provide the basic understanding of phenomena, systems and processes relevant to wood construction, but it will not provide the engineering data which are necessary for engineering design. In general, it is a publication which a person would read only one or twice and is not a daily reference manual. The contents could be all or most of the material now included in Chapters 1 to 13, some of that in Chapters 14 to 16, and Chapters 18 and 21.

I would like to stress that, in my opinion, this is an excellent publication which should make a real impact on people's attitudes towards, and their understanding of, wood construction. It is essential for the accomplishment of the long-term aims of the Project, and is certainly prerequisite reading for the Manual described next. However, it seems doubtful whether financial support for this book would fall within IDRC's mandate.

(d) Manual for the Design of Wood Structures

This is a publication of engineering data (derived from research results) which are necessary for the engineering design of wood structures. Thus, it is the publication that the designer uses repeatedly in his work. It is expected that it will be revised from time to time in the future as the technology of wood construction in the Subregion grows. For the first edition, a possible chapter breakdown is as shown in the Appendix.

This publication does not now exist in the Project. However, in meetings with the Project staff which were attended by Gilles Lessard, it was stressed that this is the kind of information that has always been expected from the Project. Accordingly, the production of this Manual has been given top priority and we have been told that it will be ready in two months.

(e) Notes for a Course in Elementary Wood Engineering

During the visit, I was asked to present a series of seminars on wood engineering to the Project staff. Notes were prepared to accompany the course and are being translated into Spanish. It is expected that they will be used in similar courses throughout the Subregion and may also provide some of the information to go into the Manual. In the seminars, I gave emphasis to design recommendations and guidelines that have been generated from my design practice and research, rather than presenting "textbook" information, which is otherwise available.

II The Laboratory and Testing Program

A structural testing laboratory is being constructed at PREVI, on property of the Ministry of Housing and Construction. It will have three facilities: a shaker table for seismic simulation testing of structural systems (e.g., full-size models of houses), a test bed with a pulley system for the static testing of simple structural systems (e.g., trusses, arches, frames), and a second test bed with two large steel frames which can be used for both static and dynamic testing of structural elements and simple structural systems.

For the seismic facility, the excavation is complete and the base of the excavation has been treated with soil-cement to a depth of 60 cm. The design of the shaker table has been checked and approved by MIT and it has now been fabricated. The remaining assembly will require six more weeks, and the facility will be ready to accept test specimens, it is predicted, in two months.

The test bed for trusses was under construction at the time of my visit. The designs of the load application and lateral support systems were developed with the Project staff. It is predicted that it will be ready to accept test specimens in one month. Four trusses have been designed by Sr. Arbaiza as test specimens; fabrication of one truss had begun.

The other test bed was ready to use but no test specimens for this facility had been prepared. Moreover, it appeared to me that there was no great sense of urgency to fabricate any test specimens. This was the second reason for my disappointment and chagrin because, in my visit in October 1976, considerable time and effort was expended in cooperation with the design team to prepare a detailed program of tests, complete with a timetable supplied by them indicating that the final static test would be completed by June 1977. When I arrived in July 1977 neither were the tests even started nor was there any apparent desire to start. No convincing reason was given for the lack of progress.

This aspect of the project was discussed at length, and, as a result, the administration of the laboratory and of the testing program was modified. Within a week the hydraulic system for applying static loads was tested, and a number of composite column test specimens were fabricated and tested. From these tests it will be possible to directly formulate design information for the chapter on columns in the Design Manual. It is evidently not possible to carry out the complete testing program which was agreed upon last October, particularly with the high priority given to the production of the Design Manual. In trying to look realistically at what can be accomplished I would recommend that the Phase I goals for the PREVI laboratory be the following:

(a) to complete the testing of the 60 specimens in the composite column portion of the program,
(b) to complete the preparation of the pulley testing system and to test the four trusses designed by Sr. Arbaiza, and
(c) to complete the preparation of the seismic facility and to verify that it works properly by means of a test on a single simple structural system.

2 There is a bad side and a good side to this situation. The bad is that Phase I will not yield any substantial number of innovative technical proposals for wood construction (either tested or conjectured) as had been expected from the beginning. The good side is that, in responding to this problem, considerable "bench strength" has been revealed in the Project. It is in the continued development of the junior staff, and in the technological and leadership capabilities of Sergio Alandia, that my cautious optimism for the future lies. Also, the shortfall in this testing program should not detract from the fact that extremely useful data have been generated in the other testing programs of the Project.

III The Grading Rule for Structural Lumber

The formulation of the grading rule and the conduct of the testing program on full-size beams and columns were discussed in detail in my previous report. The coordinator of this Project, Mr. José Carlos Cano, was on vacation during this visit and it was not feasible to carry out any further detailed review. However, the work was well in hand last October, and the work was subsequently examined in detail by Harry Booth, a consultant to the Project from Guyana. Further, Dr. Julio César Centeno has arrived from the Merida Laboratory in Venezuela to study the results and to check the derivation of allowable stresses therefrom. Taking all of this into account, I would expect a most satisfactory conclusion to this work in the near future.

IV Architectural Aspects of Wood Construction

I was asked by Sr. Tejada to review the work of Juvenal Baracco on modular coordination. As I indicated previously, I have no competence in this area and must decline to give an opinion. However, Mr. Ilmar Teng, an architect from Sweden, was at the Project for two weeks to examine Sr. Baracco's work, and it is recommended that his report be sought by

IDRC. There is one aspect of Baracco's work that is pertinent to the Design Manual: he has formulated a consistent set of 'preferred numbers' for dimensions to be used in a system of modular coordination. It appears that Perú (and possibly some of the other countries) are close to agreement on a modular coordination system and thus these preferred sizes can be adopted soon. Accordingly, Baracco has suggested preferred spans and cross-sectional dimensions for wood structural members and these sizes are being used in the span tables and section tables of the Design Manual. This will obviously have considerable impact on the future development of the lumber industry and of pre-fabricated housing.

V Summary

(a) The work on the Cartilla to date has not produced any innovative technical proposals for wood construction in the Subregion, nor does the Cartilla include the engineering data which are required for the engineering design of wood structures. Both of these were expected from the Project. However, it was agreed by the Project management that top priority in the next two months would be given to the production of a proper Manual for the Design of Wood Structures, as a companion document to the Cartilla, which is really an introduction to the principles of wood construction.

(b) The testing program to investigate new technical proposals, which was agreed upon last October, had not even been started at the time of my arrival. During my visit, the hydraulic loading system was verified and a few tests carried out on some composite columns, with further tests imminent. It appears that this test series on composite columns is the only part of the original test program which can be salvaged. This testing was done using a testing frame on a test bed in the PREVI laboratory. The other test bed (for trusses) and the seismic testing facility are still under construction. It is recommended that the work on these facilities be completed and that they be verified by carrying out a nominal amount of testing on each. This appears to be the most that should be expected from the PREVI laboratory in Phase I.

(c) It was not feasible to review in detail the work on the grading rule because of Mr. Cano's absence on holidays, but all indications are that a satisfactory completion can be expected soon.

(d) It is recommended that IDRC obtain the report of Ilmar Teng on the work by Juvenal Baracco on modular coordination.

In conclusion, thank you once again for the opportunity to be involved in the work of the Project. I have attempted to make this report more concise than my previous two; please let me know if you would like further elaboration on any aspect of my visit.

Sincerely,

F. J. Keenan, Ph.D., P.Eng.,
Associate Professor.

cc: Gilles Lessard

APPENDIX

Timber Construction Manual

Suggested Outline for the 'Manual for the Design of Wood Structures'

1. Introduction

   Purpose of this publication - scope and applicability - reference to other Project publications - a brief review of the structure and mechanical behaviour of wood.

2. The Building Process

   A general description of the various steps and choices necessary when deciding to use wood as a building material - a step-by-step general explanation of how to proceed in the entire process of wood construction - how to determine whether or not it is feasible and appropriate to use wood in a given situation.

3. Classification and Properties of Wood Products

   Standards for various wood products - the grading rule for sawn lumber - statistical values for tests on full-size graded sawn lumber beams and columns.

4. Recommended Allowable Stresses for Graded Lumber and Allowable Loads for Joints

   Methods of deriving allowable stresses and loads - tabulated allowable stresses and loads for various stress modes, species groups and grades - factors of safety - modification factors for duration of load and service conditions.

5. Design of Bending Members

   Rules and guidelines for design - bending moment, shear and deflection diagrams for various types of loading on both simply - supported and continuous beams - section properties for commonly available sizes of sawn lumber - span tables as a design aid - numerical examples.

6. Design of Compression Members

   Rules and guidelines - tables of end fixity factors for columns - formulae for allowable stresses in relation to slenderness - allowable load charts as a design aid - numerical examples.

7. Design of Beam-Columns

Rules for the design of members subjected to both axial load and bending - numerical examples.

8. Tension Members

It is not recommended to use tropical hardwoods from the Subregion in axial tension at this time.

9. Joints

For nails and bolts - glue for structural joints is not recommended at this time - rules for design - scope and applicability - allowable loads (derived from the test data) - allowable load charts - numerical examples.

10. Plywood

Difference between structural and non-structural plywood - design values are not available at this time.

11. Structural Systems and Assemblies

Types of load systems (live, dead, wind, seismic) - systems (light frame, post and beam, trusses, arches, statically indeterminate structures) - relation between type of system and feasibility of various materials - requirements for drying and preservation - bracing and connections - references to methods of structural analysis - availability of technical advice in national wood products laboratories - numerical example of complete system design.

12. Architectural Considerations in Wood Construction

Spans, heights, clearances, tolerances, ventilation, insulation, etc.

13. Standard Details for Housing

Because housing is non-engineered or semi-engineered construction, it could be useful to have sketches of details which have been shown in practice to be successful. Chapter 19 of the Cartilla contains this information but it needs to be edited in the light of regional needs and possibilities and to provide hard information on material sizes, connections, etc.

14. Electrical and Mechanical Services

Chapter 17 of the Cartilla.

15. <u>Construction Drawings</u>

Architectural drawings, structural drawings, electrical and mechanical drawings, shop drawings, standard detailing.

16. <u>Specifications</u>

How to prepare the specifications for wood in the contract documents for construction.

17. <u>Drying and Preservation of Wood Products</u>

Guidelines for appropriate methods to be specified or supervised by the designer.

18. <u>Glossary of Technical Definitions</u>

With small sketches where necessary.

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REVIEW NO. 4

UNIVERSITY OF TORONTO
Faculty of Forestry and Landscape Architecture

CONFIDENTIAL

THE STRUCTURAL UTILIZATION OF HARDWOODS IN THE ANDEAN PACT COUNTRIES:

REVIEW NO: 4 OF THE FORESTRY TECHNOLOGY PROJECT

by

F. J. Keenan, P. Eng.
Associate Professor

Submitted to:

The Director
Agriculture, Food and Nutrition Sciences Division
International Development Research Centre
Ottawa, Canada

January 18, 1978
203 College Street
Toronto, Canada M5S 1A1

CONTENTS

1. INTRODUCTION

I was asked by the International Development Research Centre:

(a) to travel to Peru, Venezuela, Colombia, Ecuador and Bolivia within the period September 30 to November 11, 1977, with an evaluation team in order to appraise the research work done in the Centre-supported Forestry Technology Project carried out by the Junta del Acuerdo de Cartagena,

(b) to make a detailed assessment of the scientific value of the research carried out to determine the strength properties and allowable stresses for structural timber, to establish grading rules for construction lumber and to test connections for construction lumber,

(c) to review for accuracy the technical material which has been prepared for publication, and

(d) to make a critical appraisal of the research program proposed for the continuation of the project.

In this evaluation mission, visits were made to the Project personnel in each of the following institutions:

- Laboratorio Nacional de Productos Forestales (LABONAC), Universidad de los Andes, Mérida, Venezuela; (1)
- Universidad Nacional de Medellin, Colombia; (2)
- Universidad Distrital de Bogota, Colombia;
- INDERENA, Bogota, Colombia;
- Centro de Investigacion y Capacitacion Forestal, Conocoto, Ecuador; (3)
- Laboratorio de Resistencia de Materiales de la Facultad de Ingenieria Civil de la Universidad Central, Quito, Ecuador;
- Facultad de Arquitectura y Urbanismo, Instituto de Investigaciones Arquitectonicas, Universidad Central, Quito, Ecuador;
- Facultad de Ingenieria de la Universidad Catolica, Quito, Ecuador;
- Centro de Desarrollo Forestal, Santa Cruz, Bolivia;
- Universidad Agraria La Molina, Lima, Peru;
- Junta del Acuerdo de Cartagena, Lima, Peru. (6)

The other members of the mission team were Gilles Lessard of IDRC and Martin Chudnoff of the U.S. Forest Products Laboratory, Madison, Wisconsin. Part way through the trip, we were joined by Doug Daniels of IDRC.

This report deals with Subprojects 3.2 (Grading), 3.3 (Structural Design) and 3.4 (Connections). Mr. Chudnoff's responsibilities are with Subprojects 3.1 (Physical and Mechanical Properties and Anatomy), 3.5 (Preservation and Drying) and 3.6 (Workability).

This is my fourth review of the Project; the others are:

No. 1 : February 2, 1976

No. 2 : January 21, 1977

No. 3 : August 12, 1977

2. SUBPROJECT 3.2 (GRADING)

2.1 Objectives and Basic Considerations

The general purpose of this subproject was to develop a classification system for structural lumber - beams and columns - which would enable the producer, the distributor and/or the user to separate wood structural members into categories according to their anticipated strength properties, and to assign allowable design stresses to the material thus graded.

Because wood, as it comes from the saw, can contain many types and combinations of defects, a system of classification, or separation between good pieces and rejects, is necessary where safe allowable stresses and loads are to be assigned to wood used in structures. If such a system were not used, the permissible load for any piece in a species would have to be set very low in order to allow for the most defective pieces that could possibly be produced in that species or species group. Thus the choice of the minimum level of quality that is set for a grade, and the number of individual grades within the system, will follow from policy decisions as to the percentage of wood produced by the sawmills which will be rejected by the grading rule for use as structural members, and as to the narrowness (or efficiency of utilization) of each grade category or level. Another consideration, which is related to the previous one, is how simple the grading rule should be when compared to the increased variability in the graded material which will accompany greater simplicity.

2.2 Methodology

The methodology originally proposed for this subproject consisted of three parts. The first part was a sawmill survey, in which information was to be collected at various sawmills in each country and then sent to the subproject coordinator in Lima, senor José Carlos Cano, for analysis and compilation. The information was to include data on the size, production capacity, machinery and personnel of each mill, the species being cut, a careful record of the characteristics and common defects of each species, and the methods of species identification which were used in the sawmill. From the point of view of the grading rule, the most important part was the recording of defects and their species-dependency.

The second part of the methodology was to calculate, from the mechanical tests carried out on small, clear specimens in Subproject 3.1, "Physical and Mechanical Properties and Anatomy", the basic stress value for each species. The allowable stress values are then calculated by multiplying the basic stress values by a "strength ratio" reduction factor, which is a number which is supposed to represent the strength-reducing effects of the defects which are permitted in the grade. This factor is determined by testing a limited number of full-size beams which contain the defect and then comparing this value to the strength of clear wood. However, during my first visit to the Project in 1975, I pointed out that the above method of determining allowable stresses has been found to be questionable, and that a more satisfactory approach is simply to test populations of full-size, in-grade, material and then base the allowable stresses on the "near-minimum" strength value of the populations. The project was then modified to test much larger numbers of full-size beams and columns than had been originally proposed. The third part of the subproject was then to promulgate a grading rule taking into account all the information developed in the first two parts.

The distribution of work between the Junta and the national counterparts was as follows. In the countries full-size material was collected from sawmills and from lumberyards, was graded according to a tentative rule prepared by the Coordinator of the subproject, and then tested as beams and columns, according to a methodology prepared by the Coordinator, with the data being sent to Lima for analysis and compilation. To assist the national counterparts in grading the material, some people were sent from each country to a grading course held in Georgetown, Guyana.

2.3 Accomplishments and Comments

(a) The sawmill survey seems not to have been carried out with much enthusiasm in all the countries. Reasons given for this are that the forms were somewhat unclear, the questions were not particularly applicable to some situations, the sawmills were hard to get to, some of the information was provided in earlier studies, etc. The material obtained is now with the Junta in Lima, but plans for its use and publication are somewhat uncertain.

(b) The beam and column testing progress in each country is as follows:

(i) Bolivia did not have facilities for full-size beam and column tests and so the material collected was sent to Lima for testing.

(ii) Peru has tested at least 20 beams of each of at least 14 Peruvian species, and the same numbers of Bolivian beams. In some cases, considerably more than 20 beams have been tested. These numbers are vague because, in spite of repeated requests, totals (as of December 1977) were not supplied.

(iii) Ecuador carried out the beam tests by means of a contract with the Laboratorio de Resistencia de Materiales de la Facultad de Ingenieria Civil de la Universidad Central, Quito. The testing is complete and consists of 488 beam tests in 14 species. No columns were tested because of a lack of suitable testing machines. 274 beams were 4 x 14 cm in cross-section and were subjected to third-point loading on a span of 2-10 m. The other 214 beams were 4 x 12 cm with a span of 2-16 m. All of the Ecuadorian project data appears in a publication produced in Quito at the completion of the project (on schedule) in June 1977.

(iv) Columbia and Venezuela also tested a minimum of 20 beams of 14 species each.

(c) The original grading rule was developed by Sr. Cano and is included as an appendix to my second report; the rule contained four species groups and two grades: I and II (plus Reject) in each species group. Cano left the project in July 1977 and all the work completed by that date was subsequently reviewed by Dr. Julio César Centeno of Mérida, Venezuela in a report "Sistema Andino de Clasificacion para Madera Estructural" dated October 5, 1977. Centeno largely rejected the work of Cano and promulgated a new grading rule, which upon close examination, appears to be similar to the Guyana Grading Rule, which was developed by Harry Booth. The similarity is not surprising, because Harry Booth helped Centeno to devise the new grading rule. Centeno analyzed all the beam test data available as of July 1977 and correctly concluded that Cano's grading rule did not effectively separate the grades in regard to strength. He also took issue with my earlier observation in Report No. 2 that Cano's grading rule did appear to be working. My conclusion was based upon a detailed examination of two particular species as well upon assurances that the behaviour of other species was the same as we had found for the two species. Upon reviewing all the data available in November 1977, it was found that the two species examined did in fact support the Cano rule but to a much greater extent than did all the other species. I conclude that I was misled, deliberately or not I cannot tell. This, incidentally, points up a quandary for visiting consultants - does one act as a resource person (as one should) responding as needed to the requirements of the workers or does one act as a policeman on IDRC's behalf, demanding to see for oneself all of the original test data? What this amounts to is whether one should treat the professionals in the project with professional trust and courtesy, or with suspicion, either of their honesty or of their competence.

At any rate, the Centeno rule is much simpler than the Cano rule, combining only three species groups, and only one grade, Select (and Reject). Consequently, the beam test data "fit" the Centeno rule better than the Cano rule. In mid-December, when I left Peru, analysis of the beam test data was still proceeding, and so a final decision on its efficacy is not available. However, it appears as though it, perhaps with a few relatively small revisions, will become a satisfactory grading rule for the use in construction of tropical woods from the Andean Pact countries. In my opinion, there is adequate data available from phase one of the project to complete this subproject, and a continuation of the work into the second phase does not warrant high priority. Due to Centeno's commitments in Mérida, Venezuela, it is not clear just how or when this subproject will be 100% complete. From the results available to date, however, it was possible to propose tentative allowable stresses for the three species groups, and these tentative allowable stresses have been used in the preparation of the Design Manual. It is strongly recommended upon its completion, that this work be reviewed externally before the Manual is published in final form. Another small potential problem area is that it now appears that, after all the beam testing, Centeno is basing his allowable stresses mainly on the results of the small clear specimen testing with the role of the beam test results being somewhat uncertain. This needs careful checking during final review of the subproject.

(d) In the tests on small clear specimens in Subproject 3.1, high correlations were found (not surprisingly) between specific gravity and most mechanical properties. This good correlation between strength and density is being used as the means for the future inclusion of new species into the species groups. This is a little dangerous, because usually such correlations are found to be considerably less exact for full-size, in-grade, material than for small clears. The same caution applies in the event that machine stress rating may be recommended for grading tropical lumber. This technique rests on the correlation between the modulus of elasticity of the material (i.e. its stiffness) and the modulus of rupture (i.e. its bending strength). This correlation, again, is generally much better for small clears than for "natural" pieces. To summarize, there appears to be no safe reasonable alternative to the testing of populations of full-size, in-grade material, if decisions have to be made about the safe allowable stress to be applied to that species.

(e) As we visited each of the national laboratories involved in the grading subproject, they were all asked if they experienced any problems. Most interviewees indicated that there had been inadequate communication with the Coordinator. There was considerable confusion apparently as to what exactly was supposed to be done, and some difficulties in knowing how to do it (particularly with classifying defects according to the grading rule). All agreed that there was a need for much more effective communications and leadership.

(f) Another problem area was the Guyana Grading Course. Although most of the people who attended felt that it was a worthwhile exercise, most also criticized the organization of the course. Complaints included too short notice, plane tickets and travel advances not being made available, the course hosts in Georgetown not being prepared for the arrival of the attendees, language problems (the course was given in English), the course being too short and/or too compressed, etc. Most of these problems would seem to be avoidable with proper management.

(g) As a positive general comment, all of the laboratories involved in the grading subproject (even the Merida lab) feel that they have benefitted by having taken part in it, both by the exercise of grading full-size material according to some rule, and by testing full-size structural members. More generally, the project itself seems to be the start of something big and important in the subregion in terms of "self-help" research.

(h) Another complaint was that the national counterparts in the subprojects did not receive all the publications which were available and relevant to their work. For example, my first report was published by the Junta and it dealt at some length with the grading, design, and joints subprojects, but it is not distributed to the workers in these subprojects. This appears to be the fault of the Junta. My second report was also published by the Junta in both English and Spanish;

it was received by some of the subproject personnel but not those in Merida; in this case, the fault (and the report) may rest with the Caracas office of the project.

3. SUBPROJECT 3.3 (DESIGN)

3.1 Objectives

There were many parts to this subproject:

(a) the preparation of the Cartilla (an elementary book on how wood behaves when used in construction) and, much later, the preparation of a Manual for the engineering design of wood members,

(b) conducting a program of research on new proposals for wood construction at the PREVI Laboratory in Lima,

(c) architectural studies: modular coordination, urban planning, climatic zonification,

X (d) conducting a study of existing wood construction in the subregion to determine why and how wood has performed successfully in the past.

3.2 Accomplishments and Comments

(a) Activity (d) was never carried out because of a lack of funds and qualified manpower. This is too bad because presumably a great deal of useful information could have been extracted from such a study. It is hoped that it will be possible to revive this work in the second phase.

(b) Activity (c) appears to have been carried out mainly, if not exclusively, by Juvenal Barraco in Lima. I understand that this work was rejected by the Coordinator of the Design Subproject, Lucho Takahashi, and consequently only fragments of it appear in the Cartilla. As I said in two previous reports, I have no competence in this particular field, and will decline to comment on the work done by Barraco. However, visiting architectural expert Ilmar Teng reviewed the work on modular coordination, and IDRC should attempt to obtain a copy of Teng's report.

(c) The research program (b) was never carried out. This is discussed at length in my third report.

(d) The Cartilla and the Manual were not complete as of mid-December, 1977. The Cartilla, however, was rapidly nearing completion and my last input to it consisted of relatively minor editorial suggestions. The Cartilla is a first-rate publication: it is an excellent pictorial and textural explanation of the factors which affect the use of wood in construction in the Andean Pact countries. Being a fundamental document, it will probably be read once or twice by a person during a formal, or self-directed, educational program, prior to attempting to use the Manual, which is designed to be used repeatedly in professional practice. However, the Cartila contains little, if any, original information, either in terms of new research data or in terms of an original synthesis of existing ideas. Consequently, it is very doubtful whether it falls within IDRC's mandate to finance the preparation of this publication. Because of this, and because of the obvious value which this publication will have in the development of wood construction in South America, it may be in order to discuss with CIDA whether they could support this activity.

Work on the Manual started only in July 1977 during my third visit when it was discovered that there had been evidently no intention to include in the Cartilla any real information on how to design or build a wooden structure of any kind, or any engineering data that had been derived from the testing program. It had always been understood by IDRC that this information would be produced. The Manual was then begun in order to fill this need and in the intervening six months, a considerable amount has been done - largely original - and a very useful document, possibly unique in South America, will be produced. As of mid-December 1977, a great deal of technical and editorial polishing still had to be done. Because of the importance of being sure that the allowable load values and design charts in the Manual are correct and will yield designs that be both economical and safe, it is important that this publication be very carefully checked, and then reviewed by international wood engineering experts. My involvement in the preparation of the Manual will continue by mail in early 1978. The Junta's current plans are to send the Manual out for external review in March or April with publication scheduled for Fall, 1978. On the basis of past experience and because of the dispersal of the Junta team, this would appear to be a rather optimistic schedule. However, the publication is well worth waiting for.

(e) Returning to the Cartilla for a moment, the Junta decided to drop one of the chapter, "Ejemplos" (Examples), which had been prepared. This chapter was to include, for each of the five countries, examples of existing successful wood construction. This was supposed to have been done by the counterpart for the design subproject in each country, but it was done only for Peru. Therefore, for political reasons, it was decided not to use this material; this is regrettable.

(f) The Coordinator of the Design Subproject was Lucho Takahashi in Lima. He left the Project in July 1977 and consequently, no final report on this subproject will be prepared.

(g) It was difficult to determine exactly what the national counterparts had done in this subproject, but is is known that one activity participated in by all countries was the preparation of the Glossary. The Glossary is a component of the Cartilla which compares in all five countries, the vocabulary of wood construction: names of tools, structural members and connections, mechanical properties, etc. There is remarkable regional variation in this nomenclature and this was quite a necessary exercise. Along with the comparison of names in the Glossary, a single name is suggested for each item and it is proposed that this name be used throughout the subregion.

(h) Other counterpart activities were seen in Colombia, Ecuador and Venezuela. In Colombia, we were shown a two-volume report on wood construction prepared by a group of architects which is said to have been produced as a result of the project. In Ecuador, a group of fourth-year architecture students prepared an hour-long videotape of structural wood utilization, starting with an exposition on tropical trees and forests, including descriptions of all the standard tests carried out in the project, and ending with footage on tests which they had designed of model wooden trusses. This was a very good piece of work and an excellent example of the kind of infrastructure that the project is supposed to foster. In Venezuela, we saw a prototype wooden house which was designed for the Guyana region by a group of people including Dr. Centeno and others at the Merida Laboratory (this activity was not part of this project).

(i) For the future (this is described in the fifth chapter of this report dealing with phase two), the Manual will form the basis of seminars for professionals and of course for engineering and architecture students at the universities. It should be recognized that the Manual represents the state of the art of wood engineering practice at any given time and thus must be revised from time to time as more research is completed and as more experience in the engineered use of wood is gained. In contrast, the Cartilla is a treatise on fundamentals and thus should need much fewer revisions, probably for editorial reasons.

(j) In talking to the national counterparts for this subproject, it was again mentioned that the single greatest problem area was with communication and coordination; there was apparently very little. At the same time, it was conceded by the counterparts that there was not enough money available in the subproject for them to devote a great deal of effort to the work.

(k) Within the design project was the program to assemble a new structural testing laboratory at PREVI in Lima on land belonging to the Peruvian Ministry of Housing and Construction. A detailed description of this facility appears in my third report and does not need repeating here. In mid-December, 1977, of the three testing facilities at PREVI, only the pair of frames for static testing of wood elements was completed. Following completion of a great many beam and column tests, it was standing idle. The truss testing facility was nearing completion. Work on the seismic testing facility was continuing (after a number of false starts) but based on experience, it would be folly to suggest a completion date for it. As described in detail in my third report, virtually none of the work originally proposed for the PREVI Lab has been carried out. IDRC was clearly misled in regard to the Junta's intentions in this area.

Plans for the use of the PREVI Lab are growing prodigiously, including the intention to build a weathering chamber large enough to accept entire houses. Also planned is a system of tracks and platforms and a railway-type turntable enabling full houses to be built and shuttled around the site from their construction area to the weather chamber to the seismic shaker to a storage area. There appears to be more enthusiasm for building a monument than for leaning about wood construction; the site has the potential of becoming a very expensive white elephant. The time has come to look very carefully at exactly what this laboratory's future role should be. In chapter five of this report, a proposal for the future development of PREVI is put forward. Incidentally, two other problems at the PREVI Lab could be noted. One is that the project's relationships with the owner of the land, the Ministry of Housing and Construction, are somewhat strained and there is continuing lack of clarity as to the Junta's tenure on the land and its ownership of materials and equipment on the site. The other problem is that, in the eyes of many non-Peruvians, the PREVI Lab is seen as a Peruvian facility and not an Andean Pact laboratory. Obviously, efforts have to be made to counter this false image.

(l) Another problem that could be mentioned is my perception of a lack of dedication to the project on the part of some members of the design subproject, as revealed by periods of incredibly low productivity while on full salary. One example is described in detail in my third report. The cause couldbe a conflict of interest due to some of the project workers having outside commercial interests and professional practices. The contracts for professional workers in the second phase should be written to reduce the possibility of this kind of abuse. A related problem is the matter of international trips. It is difficult to see how much benefit for the project as a whole has been received from at least three of the international trips undertaken by members of the Junta group, particularly because no satisfactory reports of the trips were produced. This obviously needs much greater control in phase two.

(m) In view of the common prejudice against wood construction because of its flammability, surprisingly little attention was paid to the fire resistance of wood, or to fire retardant treatments, or to the limit or urban planning or structural design which reduce fire hazards. This also will evidently have to be considered before wood can be used for high density housing in urban areas.

4. SUBPROJECT 3.4 (JOINTS)

4.1 Objectives and Methodology

These are described in detail in my first report, and insofar as they have not been significantly altered during the project, they are not repeated here.

4.2 Accomplishments and Comments

(a) This was fairly straightforward testing and the specimen preparation and testing methods were well documented in the ASTM Standards and Junta publications. The testing has been completed except at La Molina University in Lima, because log collection and delivery problems have constantly delayed the project and at Medellin, Colombia, because of money problems. Completion is anticipated by early 1978. The tests results are being analyzed by computer in Lima under the direction of the Subproject Coordinator, Dr. Centeno of Mérida, Venezuela.

(b) Centeno also plans to carry out studies of correlations among connection capacity, diameter and specific gravity values in an attempt to generate a general mathematical model for the resistance of nailed and bolted joints used in tropical hardwoods. This work is not complete, and because of Dr. Centeno's commitments in Mérida, it is difficult to predict when this work will be complete and a final report prepared on the Fastenings Subproject.

(c) Communications and coordination were regarded as poor in this subproject also. According to Centeno, it was because the Junta did not give him adequate travel money to visit his counterparts at the appropriate times and because mail and telephone services from Mérida are allegedly very poor. There was possibly some confusion at one stage as to whether it was Senor Cano or Dr. Centeno who was actually the Coordinator. This is the kind of problem which can be minimized by proper management from the Junta. Also, other means of communication, e.g. telex, should be investigated for project communications in the future.

(d) Centeno at one time distributed a commentary on the joints testing program to the national counterparts; this commentary indicated that wax paper should be used in the test specimens to reduce the effects of friction in the foints. It is alleged that Dr. Kauman, on one of his visits to the project, advised workers to ignore this provision. Consequently, about half of the countries used wax paper and half did not, leading to some problems in analyzing and comparing the test data. If this is in fact what happened, it constitutes unwarranted interference with the normal lines of communication and authority within the project, and undermines the role of the Subproject Coordinator. In Chapter 5 are listed a series of proposals for the improved management of visiting experts.

(e) It appears that Dr. Centeno intends, when he derives the allowable design loads for nailed and bolted joints, to use the same factors of safety as are now used in North American codes. I don't agree with this. The North American values have been found to be satisfactory for North American purposes after many decades of satisfactory experience in construction. In South America, this experience does not exist, and only a limited number of tests have been carried out. It would thus appear to be prudent at this time to use factors of safety considerably greater than the North American ones.

(f) The members of the evaluation mission were delighted to see that the workers in the national laboratories who carried out the joints (and other subprojects) appeared to do so with enthusiasm and dedication, and in several instances generated innovative proposals for future research. In these terms, the project has been highly successful.

5. PHASE TWO

5.1 Objectives of the Second Phase

This chapter is a bit difficult to write because the proposals of the Junta for the second phase of the project do not remain fixed long enough for one to completely evaluate them. Therefore, it is necessary to deal with the proposals in somewhat general terms rather than specifically at this time. Also, one has to go beyond the official documents which have been prepared and to comment on matters which are known to be under discussion but which have not yet been set down on paper. Accordingly, the following comments are based upon an undated document prepared by the Junta approximately in mid-November 1977, as well as upon discussions held with Marcelo Tejada and Gilles Lessard.

Most generally, the purpose of the second phase is to develop prototype wood housing forthe Andean Pact countries. In accomplishing this, it is proposed to do many things, as follows:

(a) to generate more data of the type produced in the first phase, i.e. subjecting additional species to the same tests as were carried out in the past two years;

(b) to conduct, primarily at the PREVI (or now "LADIMA") Laboratory in Lima, the static and dynamic tests on structural components and systems which were originally supposed to have been done in the first phase (reference my report of January 21, 1977);

(c) to conduct, at PREVI and to a lesser extent elsewhere, new types of tests on structural members and assemblies (these are described in detail later);

(d) to build a weathering chamber at PREVI large enough to accept entire houses so that environmental effects can be observed on full-scale houses;

(e) to conduct studies of the building process so that it can be rationalized and standardized, including the development of a system of modular coordination;

(f) to conduct feasibility studies regarding the establishment of plants for the prefabrication of wood houses;

(g) to build prototype housing in the various countries of the Subregion;

(h) to conduct courses and seminars throughout the Subregion on the design of wood structures.

5.2 General Comments

(a) My first comment is that the greater part of the proposals I have been exposed to are far too general and too vague to warrant serious evaluation. There is much evidence that the proposals have not been completely thought through, and also that technical appraisal and input to them has not been made by many of the key researchers who will have to carry out the work. This was made very evident to the evaluation mission as we enquired of the technical people in each country what they knew of the second phase proposals. Generally, they knew very little.Because of the broad sweep of the second phase and the large amounts of money requested, there is every reason to pause now and to think out carefully and discuss widely and in detail what should be done next. I strongly recommend that IDRC not be rushed into a decision on the second phase; there is little to be lost by waiting and much to be gained.

(b) Some of the work proposed is development and not research and thus is simply not within IDRC's mandate as I understand it, but may be within CIDA's. As indicated below, it may be to the mutual advantage of all parties for IDRC to enter into discussions with CIDA as to how the two agencies can cooperate in supporting various portions of the second phase.

(c) In the proposals for mechanical testing of members and components, it appears that by far the greatest amount of work (and certainly the most interesting part of the work) is to be carried out at PREVI and relatively little in the laboratories of the other countries. As indicated a few times previously in this report, the members of the evaluation mission were most favourably impressed by the work and by the workers in the national laboratories - there was enthusiasm for the work,there was a conscientious attitude towards doing the work carefully and on schedule, there were many new ideas and proposals for future work. In contrast, I have developed a rather negative attitude towards many of the Junta group in Lima: not once has any deadline for any part of the work ever been met; as indicated earlier on at least two occasions, we have been deliberately misled as to the intentions and the findings of parts of the work; there is evidence of a cavalier attitude towards how IDRC's money is to be spent; there is widespread bickering and infighting within the group; there is a dangerous combination of arrogance and incompetence in some of the members of the group. Trying to be objective and to put aside personal feelings regarding the Junta group, I am still led to the conclusion that the project (and the countries) will be better served by IDRC supporting the national laboratories to a much greater extent than in the first phase and by reducing its support of the Lima group. This does not apply to the Mérida Laboratory in Venezuela. This lab is fully developed and has been for some years. However, Venezuela does not really need foreign aid.

5.3 Does Low-Income Wood Housing Make Sense?

Before dealing with the specifics of the proposals, it could be worthwhile to review for a moment the fundamental precept of this project, which is, as I understand it, that the Andean Pact countries have an immense underutilized resource - the forests of the Amazon basin - and a desperate need for wood housing. Therefore, according to the Junta, the forest stand should be more greatly utilized for the production of building materials for houses, principally lowcost houses in order to help the sector of the population which has the poorest shelter. This sounds marvellous, but perhaps the two parts of the problem could be examined a bit closer.

First, the need for wood housing. After the evaluation mission (which was my fourth visit to South America for IDRC) I travelled throughout Peru for about a month, trying to develop some understanding of the relationship among Peruvians, the various climates in which they live, their various socio-economic levels, and their shelter - with particular reference to the actual or potential role of wood as the building material of the shelter. There are hazards in pretending to understand something this complex after such a short time, but a few things did become evident quite quickly. With the exception of the more affluent levels of Peruvian society, and with the exception of the large urban centers like Lima-Callao, Arequipa and Trujillo, there has developed a highly appropriate and natural form of housing in the jungle, in the mountains, and in the desert. In the mountains, the construction material of the lower-income groups is adobe for walls and wood poles or hewn rafters for the roof framing covered with tiles, thatch or metal. It appears that a man living in the mountains has the skill to build himself an adobe house, and he can use the natural materials which are free on his land - mud, straw, water and sun. Unless the Andean governments propose to provide lumber and tools free to the campesinos, it is hard to see why wood would be preferred to adobe. In the desert regions (and in the green river valleys which intersect the coastal desert) the materials are adobe and also woven panels made of split cane supported on wood pole frameworks. Again, the cane is locally available on the land (quite abundantly in some areas) and provides both ventilation and protection from sun and sand. This type of housing accompanies a rather primitive lifestyle; however, it is not the shelter itself which is primitive but rather the lack of services and furnishings inside the house.

In the jungle, it is a pole frame structure with a raised living platform, mainly open sides, and a steep roof thatched straw or palm leaves; it seems to be perfectly in balance with the combined need for ventilation, drainage and protection from rain and animals, it is readily constructed from the materials at hand and it is adequately durable for the semi-nomadic life style of the Indians. A wooden house in such a setting would be ludicrous.

In the cities and towns, the materials are usually concrete, brick, stone and adobe, with gypsum plaster. Again excluding the houses of the relatively affluent, it is clear that the typical close proximity of houses in urban areas would constitute an unacceptable fire hazard if the dwellings were made of wood. It is worthwhile to recall that Lima has only a volunteer fire brigade, and it was demonstrated last summer to be woefully inadequate to cope with a fire of any magnitude.

If there is any validity at all to the above observations, it would follow that low income housing for the Andean Pact countries might not advantageously be produced from tropical lumber. In contrast, it is possible to see it used in more expensive housing, in which it could be designed to provide beauty, strength, resistance to fire, permanence, and possibly economy. It has real potential also for industrial, commercial and assembly buildings. Another area where it could be very useful is in prefabricated buildings which have to be transported some distance and erected relatively quickly, e.g. for mining, construction, and military camps. Another possibility at this time, as the Peruvian sol is steadily being devalued, and the country's need to utilize natural resources to earn foreign exchange is so great, is the export market for prefabricated wood construction; the particular benefit here is in exporting finished or semi-finished products rather than raw materials. Developing countries can find themselves in a good world competitive position if they can "add value" to the natural resource before exporting it.

Incidentally, if it is true that the sector of the population which might benefit the least from the development of sawn lumber as a building material - the indigenous low-income population - then an aid agency like

IDRC which presumably is more interested in improving the quality of life for those most in need, is faced with a bit of a quandary.

The above paragraphs looked at one side of the problem - the need for wood housing. The other side is the capability of the tropical forest to be utilized to a much greater extent. Two of IDRC's recent publications * have pointed out the potential dangers of increasing the harvest from the tropical forest without proper supervision and silvicultural management. Because of the great complexity of the tropical ecology, because of the sensitivity of the tropical forest to harvesting, and because the professional practice of forestry in the subregion is still evolving, there appears to be a real need to evaluate carefully what this increased exploitation will do to the forests of the subregion.

Taking all of the above comments into consideration, it is clear that a careful re-evaluation of the purpose of the project is called for. There is a real need to consider carefully who will make use of the sawn lumber, and of the construction technology, that will be generated as a result of the second phase. Although there is a desperate need to improve the quality of much of the housing in Latin America, it is not clear that sawn lumber will provide the means of so doing. It is possible to suspect that the opportunity to stimulate the economies of the Andean countries by exploiting the forest resource has produced a rather artificial enthusiasm for wood housing.

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* Bene, J.G., J.W. Beall and A. Côté, 1977. Trees, food and people: land management in the tropics. IDRC.

Sanger, C., L.G. Lessard and G. Poulsen. 1977. Trees for people, IDRC.

5.4 High Priority Research

Having said all of the above about the need to re-assess the objectives of the project, let us suppose that such an exercise has been carried out and that a rationale for proceeding with research on light wood construction has been successfully defended; then, what areas of research should receive highest priority? In my opinion, it is essential to understand the mechanical behaviour of the wooden structures being considered, i.e. the response of the wood structural systems, in terms of resistance to fracture and deformation, when the anticipated loadings due to service conditions are applied, i.e. the forces due to wind, due to earthquakes, due to the weights of the people using the structure and their furnishings, equipment, etc. In terms of the specific tests suggested in the Junta document mentioned earlier, I would suggest high priority to be given to the following:

(a) development of designs for roof trusses and their joints, and static load tests on the trusses;

(b) static axial compression tests on studs and columns (the column proposal could be modified to check the design method for columns of any slenderness, rather than simply carrying out mass testing of columns at various slenderness values);

(c) static tests on beams and joints to see the effect of duration of load on the strength of beams (this seems to be particularly important in the Subregion where, on some roof members, these could be a high ratio if dead load to live load, i.e. the greater part of the design load would be permanent; we also suspect that the duration of load response of tropical woods will be closer to that traditionally assumed in North America rather than behaving like the newly-discovered "fifth percentile" response of temperate conifers);

(d) static tests of beams of low density (0.3 to 0.4) (it is claimed that it has been recently found that a substantial number of tropical species are within this specific gravity range; if this is indeed so, their low density could result in much easier handling, sawing, drilling, nailing, and thus they would be eminently suited for construction);

(e) static and dynamic tests on composite wall panels (this is particularly useful because this will tell how various construction of walls - framing plus exterior cladding plus interior finish (if any) with and without openings for windows and doors - will resist vertical and horizontal loads applied both statically and repetitively);

(f) seismic simulation tests on ~~entire house units~~ structural modules using the shaker facility at PREVI (but perhaps with simpler instrumentation than is proposed)

Incidentally, some other tests which might be included are determining the durability of nailed and bolted joints. It is well known that the chemical reactions which take place between the extractives in some species and the metal fastener can result in a deterioration of the joint, particularly if the wood is in the green condition. It would be worthwhile to examine this aspect of the performance of connections before any final design proposals for joints are promulgated.

5.5 Location of the Research

The next question is "Where should these tests be carried out?" The seismic simulation tests (f) and the dynamic tests (e) would probably have to be carried out at PREVI because the expensive and specialized equipment for this type of work exists only there. In fact, this is probably the direction that the PREVI Lab should grow in - towards being an Andean Laboratory for Dynamic Testing - and there is no reason why it should be restricted to wood construction. It should have an international policy committee to formulate research programs. Strong efforts should be made to avoid its having a Peruvian identity; it should be, and should be seen to be, a subregional facility.

However, with respect to the static tests in the above list, these should be carried out as much as possible in the various national laboratories of the Subregion. In terms of developing national technical infrastructures, distributing the testing work will be much more productive than, say, bringing the various nationals to PREVI to work there. Another reason is that each country will have its own preferred species for investigation, and it becomes unnecessarily expensive to ship this material to Lima. Also, for the wall systems tests, each country will have its traditional methods of framing and cladding a wall, and the program should be responsive to these preferences.

5.6 Low Priority Research

The proposed tests to which I would assign <u>low</u> priority are the following:

(a) construction of a weathering chamber for full-size houses (this is an enormously expensive method of generating a minuscule amount of information; the idea is just plain silly);

(b) static tests on beams of high density (0.7 to 0.9) (this species is a declining component of the tropical forest, the wood is very difficult to work with in construction, and these species can be safely and conservatively utilized using the allowable stresses already determined for less dense species);

(c) axial tension tests on full-size lumber (structural lumber is virtually never used in axial tension; the only significant place is in bottom chords and some webs of trusses and truss tests are already recommended for high priority);

(d) shear strength of full-size pieces (shear strength is rarely critical in light construction; some auxiliary tests could be carried out in the laboratories but these don't warrant consideration as a full-blown subproject);

(e) effect of moisture content on strength (this is always useful information to have but, compared to all the other work of much greater significance that is proposed, it should receive low priority at this time; also, dry lumber (which is stronger is green lumber) can be safely and conservatively used in construction using the allowable stresses already generated for green lumber);

(f) duplicating the tests of the first phase on additional species (aside from the species mentioned above in regard to density ranges, we already have test data for more than 100 species from phase one; this is a lot of information and it is a better use of resources at this time to build upon the existing data rather than to broaden the database; this proposal is largely a "make-work" proposition put forward by the Junta to give the national labs something to do in phase two. As described above, there are possible activities for the national labs which will be much more worthwhile and educational.

5.7 Development Projects for Possible Support by CIDA

Some of the proposed work, as indicated earlier, is development activity and could be considered for support by CIDA.

(a) One such project is the setting up of seminars to be presented throughout the Subregion to introduce people to the Cartilla and the Design Manual. This wouldbe directed primarily towards engineers, architects, builders and students. It should show them how to use the publications to aid them in the design of wood structures. Because of the variation of traditional construction throughout the Subregion, the team presenting the seminar should include at least one local national engineer or architect who has been involved in the work of the first phase. There is obviously room in such an exercice for outside consultation with European or North American experts on the design of such seminars, but the actual presentation should obviously be only by nationals.

(b) A second development area is the rationalization and standardization of the construction industry including the development of a system of modular coordination, studying the feasibility of industrialized prefabrication and the erection of prototype housing. This may or may not be a useful activity but the necessity for it and the methods of doing it are so vaguely expressed that it requires considerably more work in preparation before it can be seriously assessed.

(c) Another subproject which might be considered is a study of traditional methods of wood construction in the Subregion to see what lessons for the future can be learned. As in many other societies, there exists a substantial body of "folk" knowledge, particularly about organic materials, which is largely ignored when a new technology is being produced. Wood has been used successfully in South America since colonial times, and it would benefit the present work if we could study exactly why the earlier usage was successful. Incidentally, the activity was proposed for the first phase but was dropped for lack of funds and lack of qualified manpower. Ideally, the assessments involved here might best be made by a three-man team consisting of an architect, a structural engineer, and a wood technologist.

5.8 Role of the Junta in Phase Two

It follows from the above that the role of the Junta would be considerably smaller in the second phase than in the first. And this is as it should be. What then will be their major activity? First, they should have the responsibility for mounting the wood design seminars described earlier. Secondly, they should have the responsibility to see that a good level of communications is maintained among all the participating groups. Emphasis here is on "maintaining communications" as distinct from management or direction. Included in this is the responsibility for editing, producing and distributing all publications produced from the project. The third activity would be to operate the PREVI Laboratory on behalf of an international policy committee. The fourth activity is to coordinate and organize international travel. This would include both internal consultation and training (visits of workers from one country to counterpart activity in another country; and training programs within the Subregion) and external consultation and training (bringing experts to the Subregion at such a time and with such an itinerary as to maximize their usefulness to the project; and foreign training and fellowships for project workers).

5.9 Proposals for Improved Management of Visiting Experts

One area that needs improvement in the second phase is IDRC's management of foreign experts who are brought to the Subregion to assist with the project.

(a) IDRC regards its visiting experts as being in two distinct categories - those who are brought in to assist the project workers, and those who are brought in to assess the work being done on behalf of IDRC. The project workers often have not been made aware of this distinction and naturally expect all experts to be in the first caterory, i.e. helpers. This leads, in some cases, to considerable disenchantment with the expert (and with IDRC) In some cases, the expert himself may not fully appreciate the distinction, and this leads to confusion and frustration on all sides. Often it is possible for a visitor to play both roles in spite of the terms of reference of his consultancy, but this is more by good luck than by good management. Obviously, IDRC should make clear to the expert, particularly to his project hosts, exactly what the expert's role is supposed to be. In cases where a country has requested the visit of an expert, that country should take part in drawing up the terms of reference of the consultancy.

(b) Another type of problem arises when a visiting expert regards himself as a decision-maker in the project, and not, according to the IDRC philosophy, as a resource person. In phase one, this happened on at least one occasion and the position of a subproject coordinator was completely undermined. This circumstance indicates that IDRC must make very clear to the visitor that project decisions must be made by the nationals, and in accordance with the proper lines of communication and authority.

(c) One complaint heard in the countries about visiting experts is that, while they may be very capable technically, they can be woefully ignorant of life in that country, i.e. the geography, political system, economic situation, and social customs. Apparently, ignorance of these matters is regarded as being more serious than ignorance of the country's language. From the point of view of

IDRC's image, it would seem to be worthwhile to make sure that consultants receive some sort of briefing material on the country prior to their first visit there.

(d) On the matter of language, the effectiveness of a visit is very much dependent upon the visitor's facility in the national language quite in spite of the presence of translators. If IDRC plans to use an expert more than once in a certain country, it is very much in IDRC's interest to subsidize any language training that the expert undertakes in connection with his continuing involvement with IDRC.

(e) Another problem area relates to IDRC's management of time during visits of groups of experts. In the evaluation mission for this project, there were several instances where the time for effective discussions between the visiting experts and the local workers was severely curtailed due to courtesy or political visits, due to mandatory social activities, due to group discussions which may or may not have coincided with an individual's assignment on the mission. IDRC has spent enough money on getting the expert to a particular place that every effort should be made to manage his time to produce the most effective result to IDRC and to the project.

(f) In the case wherethe project personnel are the hosts for a visiting expert, IDRC should attempt to monitor the plans for his visit so that sufficient time remains for discussions with all the workers who will benefit from his visit. It is very easy to underestimate the amount of time that a visiting expert will spend on eating, sleeping, socializing, travelling, tourism, shopping for souvenirs, reconfirming his flights, checking into hotels, and recovering from jet lag.

5.10 Fellowships

In terms of the technical and professional growth displayed by many individuals throughout the Subregion as a result of phase one, the project should be regarded as an unqualified success. Ecuador and Bolivia in particular, started from virtually nothing in the wood construction field. Two or three years later, they have developed test equipment and facilities, they have logged many hours of research experience in all the areas of the project, and now there is considerable enthusiasm to continue developing . It appears that many of the individuals in the project could benefit from travelling to obtain training in research techniques or professional education in the areas of engineering and architecture.

The first type of travel - for training - is possibly best done within the Subregion, i.e. travel from a less experienced laboratory to a more experienced one like Mérida. These would typically be of short duration, and should be carried out as training programs within phase two, once phase two gets started. No language problems are presented with this type of training. I can offer no recommendations as to who the most appropriate individuals might be.

For some of the professional engineers and architects in the project, travel away from South America would likely result in the greatest improvement of their capabilities and their potential service to their countries. These programs would be of much longer duration (6months to two years) and could be started either immediately or after phase two begins. Obviously, current or potential ability to work in a language other than Spanish is called for. Possible institutions which could provide satisfactory education are, for example,

(a) the program in Timber Structures and Technology at Imperial College, London;

(b) Centre Technique du Bois, France

(c) several North American universities, e.g. Purdue, Washington State, Wisconsin, Syracuse, Toronto, Laval, UBC, Cal. Tech., and others.

Three individuals who have displayed interest in such a program and who could benefit from such an experience are:

(a) Christian Arbaiza, Lima, Peru

(b) Nelson Toledo, Conocoto, Ecuador

(c) Octavio Lopez, Medellin, Colombia

Surely there are others, but these are the ones who were noticed.

5.11 Liaison with Government Ministries and Industry

The work of phase one was distributed throughout the five countries in conjunction with several national agencies, many of which were government industries. Generally speaking, these ministries were the ones with the responsibility for forestry or natural resources. This was logical, because phase one was a program based on the exploitation of a natural resource. Phase two, however, is a little different in its emphasis. We already have the raw properties of the resource and it is the industrial utilization that is being studied. Accordingly, it is possible that a greater involvement with other government ministries may be appropriate e.g. Ministries of Housing, Industry, Urban Planning, etc. In fact, I have been contacted by the Peruvian Ministry of Industry and Tourism about their potential role in the second phase, and in Bolivia, we spoke to representatives of the Ministry of Housing and Urban Planning. Their eagerness to participate should be welcomed.

As we travelled through the Subregion, we inquired as to the relation between the project and the local industry. In many cases, there was no contact. In others, there was a gradually increasing number of enquiries made by industry to the labs where the work was proceeding. It appeared that, at most, the project reacted passively to the surrounding industry. In phase two, this won't be good enough. Strong efforts should be made to keep the wood industry (and engineers, architects, builders and the standards institutions) informed of what is happening in the project and how they can benefit from the results of the research. It is never too earlier for technology transfer.

69142

Report No. 5

done for JHNAC

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY

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FJK/JT 7th April 1978

Sr Ingeniero
Marcelo Tejada V
Jefe, PADT - REFORT
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Lima, Peru

Dear Marcelo

Because I did not see you during my trip to Lima March 16th - 24th, I am writing to summarize my comments. In this report I will discuss the Manual, the system of classifying lumber species according to density, the strength of Tornillo, the derivation of allowable stresses and the factor of safety, standard lumber sizes, possible activities in the second phase, and a few other matters.

1. The Manual of Wood Construction

The major activity during my visit to Lima was a detailed review of the Manual and especially of those chapters relating to structural design. My first observation is that the Manual has the potential to be an excellent publication. Some first-rate, and original, work has been done by Roberto Machicao with the assistance of Christian Arbaiza. I am sure that when the Manual is complete, it will be of world stature. I would recommend that full support be given to the completion and, later, to the dissemination of the Manual throughout the Subregion.

Roberto, Christian and I discussed hundreds of suggestions for improvement to the Manual. Obviously I won't list all of them here, but they do exist in writing and are with Roberto, either in the form of memoranda or as marginal notes in a marked-up copy of the Manual. A few of the major general comments follow.

A re-organization of the sequence and contents of the chapters is needed so that information which is used on a day-to-day basis in design is separated from reference information which is looked at only infrequently. Also, a more expansive Introduction chapter is needed to introduce the reader to wood construction in the Subregion; this would be in addition to the existing Introduction which is really more of a Preface. The Preface should make detailed reference to the other Junta publications. Finally, an effort should be made to achieve more continuity or flow from one chapter to another, and this should obviously be done only by someone who really understands the engineering content of the Manual.

Another general comment is that there are too many "standard" sizes of lumber ~~tested~~ listed in the graphs and tables. Later in this report I will refer to a method of reducing the number of standard sizes and of the choosing the most rational set of sizes.

The chapter on Joints is incomplete presumably because the final report on the Joints Subproject is still not finished. This also means that the truss design chapter is incomplete because the data for the design of truss joints is missing. I would recommend that Roberto adopt for the Manual conservative values of nail and bolt design data from the world literature and use them now in the Manual, rather than continuing to wait for the results of the Joints Subproject.

With all of the design aids in the Manual, many of which will be unfamiliar to the users in the Subregion, there is a need for several examples and illustrations distributed in the Manual to show how to use the graphs and tables. Also, there is a need, at the end of the Manual, to carry out a complete design of one or more wood structural systems to show how to apply and how to integrate all of the information in the Manual to produce a total structure. This should also include the specification of the wood products, an activity which normally accompanies design.

Another area of incompleteness by others, which is delaying the finish of the Manual, is the Grading Subproject. Without the final report on this, we have only tentative allowable stresses upon which to base all the design charts in the Manual. It is recommended that efforts be made to complete the Grading Subproject, and to have it externally reviewed, as soon as possible. Incidentally, having read Harry Booth's comments on the grading rule, I hope that all of these will be incorporated.

2. Classification of Structural Lumber

In the Project and in the Manual, at the present time, the method of assigning particular species to species groups and of deriving allowable stresses for each species group, is based on density. This is because there exists a high correlation between density and the strength properties of small, clear specimens. However, we do not use small, clear specimens when we build wood structures - we use instead large pieces which contain the various defects which are permitted within the lumber grade. Now, the correlation between density and the strength of large, in-grade structural members is not as good as the correlation with small, clear specimens. This is particularly true at the level of the fifth percentile of strength values where the weakening influence of defects predominates over "clear wood" behaviour.

This was confirmed last week when we examined some data from tests on full-size beams with Hector Segura and Fernando Alvarez. They showed us several species which displayed fifth percentile strength values much lower than those predicted by density correlations. Therefore, the proper allowable stresses in bending for these species are considerably lower than the prescribed allowable stress for their species group, and to use these species with the prescribed allowable stress is dangerous.

To summarize, basing strength predictions on density and on the behaviour of small, clear specimens just doesn't work safely and dependably at the level of the fifth percentile, which is the level which is used for the derivation of allowable stresses.

Therefore, it is clear that some revision of this process is necessary. I recommend that the fifth percentile modulus of rupture value of the beam test data be obtained for each species under consideration and that the fifth percentile value be based upon as many beam tests as possible. Then simply rank all the species from the weakest to the strongest (based upon the fifth percentile beam test modulus of rupture value) and assign the strongest one-third to Group A, the next one-third to Group B, and the weakest one-third to Group C. The fifth percentile of the weakest species in each Group is the governing fifth percentile value for the Group and the Group's allowable stress is based upon this value.

The above procedure gives us an equal number of species in each Group. But, unless the relationship between strength and rank is linear (which is unlikely) there will not be an equal interval of strength values within each Group. Therefore, as an alternative procedure, having ranked all of the species from the weakest to the strongest, it is possible to divide the total range in strength values (between the weakest and the strongest species) into three equal parts. Group A species are those which are included in the upper third of the strength range, and so on. This will result in the three groups containing unequal numbers of species but the Group boundaries will more uniformly cover the range of strength values.

3. The Strength of Tornillo

Fernando and Hector showed me some extremely low beam test values for Tornillo: two or three beams, which apparently satisfied the grading rule, had modulus of rupture values less than 100 kg/cm^2. Considering that the Group C allowable stress is 140 kg/cm^2, this implies a fifth percentile value of $140 \times 2.1 = 294\ kg/cm^2$. It is clear that something is very wrong here. We went to the Previ Laboratory to examine several tested Tornillo beams; a third of them had high strength values, one third moderate strength, and one third low strength (less than 100 kg/cm^2). Upon close examination, it was seen that the weakest beams each had several very fine, barely visible lines of compression failure wrinkles running across the grain. (These were distinct from the compression failure wrinkles which developed during the test because they occurred throughout the beam and not just in the high-compression zones). The beam failures were brash or brittle and were associated with these wrinkles. I expect that these compression wrinkles were caused either during felling of the tree or, more likely, due to growth stresses in the standing tree ("brittle heart").

There were no compression wrinkles seen in the strongest beams, and only a few in the beams of moderate strength.

Therefore, in the case of Tornillo (and possibly other species) it will be necessary to examine every structural member very carefully to exclude any member which possesses compression wrinkles.

Because the strength of Tornillo is acutely sensitive to the presence of these barely visible defects, because its strength depends very much on the altitude of the site it comes from, because it is generally weak, flexible and highly variable, it is necessary to ask whether allowable stresses should be assigned to Tornillo at all. This is a question relating both to public safety and to developing Subregional confidence in the use of wood, and is asked in the full awareness of Tornillo's current widespread use in Peru.

4. Derivation of Allowable Stresses; Factor of Safety

Currently, the allowable stress in bending is obtained by dividing the fifth percentile value of modulus of rupture by 2.1 or 2.2. This value is the product of 1.7 and 1.3, where 1.7 is the ratio of short-term strength (10 minutes) to long-term strength (10 years) and 1.3 is the "true" factor of safety. In my opinion, this value is too low. The main reason for my opinion is that there exists in the Subregion very little experience in the engineered use of wood, and in the use of all the species included in the Project. At this time, when an attempt is being made to increase the confidence of users in the structural suitability of wood, there is every reason to be conservative. Furthermore, the previous section of this report gave a clear example of unexpected factors being present which will substantially weaken the strength of wood.

I would recommend a factor of 3.0, rather than 2.2. As experience is gained in the future, it should be possible to decrease this value slightly.

5. Standard Lumber Sizes

As I mentioned earlier, there are quite possibly too many "standard" sizes of lumber ~~tested~~ listed in the Manual; they do not agree with existing Peruvian, North American or European standard sizes. In other words, they are probably one of the worst possible choices which could have been made. At Roberto's request, Dr L G Booth of Imperial College and I made a study for you of how to develop standard lumber sizes, and I presented the results of the study to Roberto and Christian when I was in Lima. Because some of the concepts are rather difficult and require a fairly careful reading, I won't attempt to summarize our recommendations here. A report on the study is being typed and will be sent to you soon.

6. Phase Two

(a) I had a long discussion on Phase Two with Emilio Cuevas while I was in Lima, and I think that he is preparing a summary of our talks for you. We discussed the possibility that wood construction may not be appropriate for low-income housing in the Subregion unless that housing is almost completely subsidized either by the government or by industry. However, wood seems to have a much greater potential use in construction which can be prefabricated, transported some considerable distance, and erected quickly. Examples are worker housing in mining and forestry camps, and for military camps.

Another potential use is as an export commodity. This would seem to be particularly appropriate right now in the context of the need for foreign exchange and relatively low cost of labour in Peru, as well as providing a means to utilize an abundant natural resource. It might be easier to consider doing the prefabrication in factories in the forest rather than on the coast and exporting eastwards, ie down the Amazon, rather than from the Pacific coast. The people in England with whom I have discussed this suggest that this could be successful but only if the quality of the product is very high. It doesn't matter what the cost is if the quality is too low to find an export market. These comments are offered to provide some guidelines for the development of prototype housing in Phase Two.

(b) It has become clear from the results of Phase One that a very important needed area of scientific research is in developing the correlations between defects (singly and in combination) found in tropical woods, and the strength of structural members. North American data has very little applicability here. Before any truly successful structural grading rule can be developed in South America, we have to know how defects affect strength, and we have to know how this relationship varies from one species to another. It is possible that much of the raw data already exists from the beam tests of Phase One, and that what is needed is a careful study of this information by a group which includes a wood anatomist (eg Ana Maria Sibille).

One result of such a study is that we will finally be able to distinguish between defects which primarily affect the appearance of a piece from those which primarily affect the strength.

(c) Before the shear or racking behaviour of walls is studied in Phase Two, it is recommended that the current work on racking test methods in Britain and Europe be reviewed. It will save a lot of time and trouble if this is done before your tests start. Incidentally, some of the US and Canadian data on shear wall and diaphragms can be used in the Manual until data is produced in the Subregion during Phase Two.

(d) Another particularly useful Phase Two activity is the presentation of wood design seminars and courses throughout the Subregion, but these should wait until the Manual is finished. It now looks as though several months will be needed for this.

7. Other comments

(a) My expenses for the visit totalled US$ 220.89. Roberto has the details of the expenditures and also my rebate to the Junta, which consists of a cheque for US$ 74.11 plus US$ 5.00 cash.

(b) If you think that it might be useful for me to return to Lima to review the Manual once again prior to publication, I should tell you that it will not be possible for me prior to October 1978, ie until after I have returned to Toronto.

(c) This report may be of interest to IDRC. May I have your permission to send them a copy?

I trust that these comments have been useful to you. Please let me know if you would like further elaboration on these, or any other, points.

With best personal regards and wishes for the future,

Sincerely

F J KEENAN

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January 18, 1978

Mr. J.H. Hulse, Director
Agriculture, Food and Nutrition Sciences Division
International Development Research Centre
Box 8500
Ottawa, Ontario, K1G 3H9

Dear Mr. Hulse:

Re: Forestry Technology (Andean Pact) Project
Centre File No. 3-P-74-0009

Enclosed are two copies of my report "The Structural Utilization of Hardwoods in the Andean Pact Countries: Review No. 4 of the Forestry Technology Project". With a copy of this letter, one copy of the report is being sent to Gilles Lessard, and one copy goes to Doug Daniels.

The tone of the report is generally negative, because it deals with all the problems encountered in the project; nevertheless, as a general comment, I regard phase one of the project as being enormously successful, in spite of all the problems. Its success can be measured in terms of the research data generated,in terms of the publications produced (at least two, the Cartilla and the Manual, will be of world standard in terms of the number of technicians and professionals in the five Andean Pact countries who have grown and become of more potential service to the countries as a result of working in the project, in terms of the economic stimulation that will result from the increased utilization of a natural resource, in terms of a possible contribution to reducing the housing deficit in Latin America, but perhaps of most fundamental significance, in terms of the developing realization that the workers in the subregion can carry off such a major project by themselves.

Thank you once again for asking me to continue my involvement in this project. Please let me know if you would like further elaboration on any part of the report.

Yours sincerely,

F.J. Keenan, Ph.D., P.Eng.
Associate Professor
Wood Science and Forest Products

Encl.(2)

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Strength Values for Wood and Limit States Design

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Strength Values for Wood and Limit States Design

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Received February 4, 1975
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This paper describes the present method of deriving allowable stresses for wood. While this method has served adequately in the past its relevance to 'limit states design' is questioned and several of its shortcomings are pointed out.

An alternative method of obtaining characteristic values for the strength properties of wood is suggested. A pilot investigation was carried out to ascertain the amount of work involved in obtaining the necessary data. It would appear possible and practical to derive the characteristic values needed for 'limit states design' based upon 'in-grade testing'.

It is suggested that such a method could result in improvements in the present grading rules and a more efficient use of our timber resource.

L'article décrit la méthode actuelle de détermination des taux de travail pour le bois. Bien que cette méthode se soit révélée satisfaisante dans le passé, son à-propos est mis en doute quand on parle de calcul aux états limites et plusieurs de ses faiblesses sont mises en relief.

L'auteur propose une autre méthode pour la détermination des valeurs caractéristiques des résistances du bois. On a mené une recherche échantillon en vue de connaître la somme de travail qu'imposerait la détermination des données nécessaires; il semble possible et réaliste de définir les valeurs caractéristiques utilisées dans le calcul aux états limites et déduites d'essais par classe.

On estime que cette méthode pourrait améliorer les règles actuelles de classification des bois et conduire à une meilleure utilisation de la ressource bois. [Traduit par la Revue]

Introduction

The adoption of 'limit states design' in the National Building Code of Canada 1975 presents both a challenge to and an opportunity for the timber industry (Allen 1975).

It is a challenge in the sense that the industry will have to provide more relevant strength information of their products in order to take advantage of this new design concept. It is an opportunity in the sense that it allows the industry to establish a new base for the appropriate strength properties.

This paper reviews the present method of deriving allowable stresses used for structural design of wood and suggests an alternate method of obtaining relevant material information suitable for limit states design.

Present Method

General

The present method used to derive allowable stress for wood seems to have served society adequately in the past. An inordinate amount of structural failures has not been experienced. However, it is not possible to determine purely from practical experience whether some (possibly all) of the structures were overdesigned and hence were not as economical as they possibly could have been.

The present allowable stresses are based upon testing of small, clear, straight grain specimens. The test results are then modified successively by factors which are supposed to convert the test results to represent the conditions for commercial material. Allowable bending stresses are, for example, developed from testing specimens 2 in. × 2 in. × 28 in. (51 mm × 51 mm × 716 mm) in three point bending and the conversion is done according to the following formula:

$$[1] \quad \sigma_{\text{allowable bending}} = (\bar{x} - 1.645s) \times F_{\text{time}} \times F_{\text{moisture}} \times F_{\text{height}} \times F_{\text{grade}} \times (1/F_{\text{safety}})$$

($\bar{x}$ − 1.645s) Variability

$\bar{x}$ is the average of the test results and s is the standard deviation. To substract 1.645 times s implies a calculation of the 5th percentile level assuming that the distribution of the test results is gaussian or normal. It is quite common that the coefficient of variation will be in the order of 15%.

F_{time} Duration of Load

It has been observed by testing of small clear specimens at the United States Forest Products Laboratory, Madison, Wisconsin, that a reduction in strength takes place with time. Thus material loaded to, say, 70% of its estimated short term strength will fail on the average after about 2000 h (83 days). A factor of 0.62 is used to convert the short term strength to the predicted strength after 10 years.

This period (10 years) is referred to as the normal load duration for which the allowable stresses are valid, and the designer modifies the allowable stresses further to suit his particular load conditions. For snow load, supposedly lasting for an accumulated period of 2 months, the designer may increase the allowable stresses by 15%.

$F_{moisture}$ Moisture Content

This factor takes care of the change in strength as the wood dries out. The usual testing procedure calls for testing of the small clear specimens in the green condition (wet) and the $F_{moisture}$ factor allows for the conversion to dry condition.

The allowable stresses are published for dry conditions and when necessary the designer will convert back to wet conditions, for instance, if the structure is such that the wood will have an average moisture content in excess of 15%.

F_{height} Height Effect

The standard test for beams of 2 in. depth (51 mm) gives values which are somewhat greater than those observed for beams of clear material but of greater depth. The F_{height} factor converts the 2 in. (51 mm) test results to material 12 in. (304 mm) deep.

F_{grade} Grade Factor

The grade factor takes into account the maximum strength reducing defect allowed within the grade. The maximum knot and the maximum slope of grain are coordinated in the grading rules. A 60% grade indicates that the reduction in strength caused by a knot can be a maximum of 40%. Similarly the maximum slope of grain for that grade should result in strength reduction close to but not more than 40%. Other defects such as shake, split, etc. are restricted in a similar manner. The grades are described in the Standard Grading Rules for Canadian Lumber.

F_{safety} Factor of Safety

The final step is to divide by the factor of safety which is stated to be 1.3 for bending. This may seem low relative to other materials, but each reduction factor for wood has been selected conservatively and each contains an unspecified amount of safety so that the true safety factor is larger than the stated factor of safety.

For all the worst conditions to be operable at the same time, a really weak basic material with the maximum size defect would be loaded for the full duration with an overload of 1.3 in unfavorable moisture conditions, which is very unlikely.

Comments on Present Method

General

The foregoing sections describe in a general way the method of developing allowable stresses for wood. Some minor refinements have, for the sake of brevity, not been dealt with. For other strength properties the philosophy is the same but the magnitude of the factors may be different.

An exception, however, is the modulus of elasticity, where the average value for the species is used. Differentiation according to grade for this property was not made in the National Building Code of Canada until 1970.

At the time when allowable stresses for wood were first required (about 1930), many different species were available commercially, and the above method made sense because it was easy to apply to any species. However, conditions have changed. In present building codes the concept of species groups has been introduced. The 150 species of trees grown in Canada are divided into five groups of similar strength and allowable stresses are published for each species group rather than for the individual species. Species with similar strength properties are grouped together and the most conservative values have been selected to represent the allowable stresses for all the species in the group. The need for a quick method to determine the strength of individual species has thus diminished somewhat.

Allowable stresses are published for two to five grades for each species group. However, it has become increasingly difficult to buy single grades of lumber. The commercial practice of selling, for instance, '#2 and better' has forced the designer to use allowable stresses for #2 grade even though he will receive 25% #2 grade and 75% #1 grade or 'select structural'. He can not take advantage of the strong material in his design without segregating it on the job site. The 5th percentile value and therefore the allowable stress for #2 grade alone is obviously lower than for the mixture #2 and better.

If the commercial practice of marketing mixed grades of lumber cannot be changed, consideration should be given to standardize the grade mixes and publish allowable stresses for those mixes of grades and species which are commercially available.

Format of Formula for Allowable Stresses

Apart from the above general comments a closer look should be taken at the present system from a technical point of view. It can be seen from the format of the formula for deriving allowable stresses that each factor is conceived as an independent phenomenon. However, as will be discussed later this is not so and the method is therefore an oversimplification which may very well work to the detriment of the lumber industry.

Variability

As mentioned the statistical treatment of the test results was predicated upon the assumption that the population has a normal distribution. This may be correct for clear specimens. However, it has been found that strength distributions of commercial material, to which the allowable stresses are applied, are not necessarily normally distributed. For instance in a test of two hundred and forty 2 × 6 Douglas Fir joists it was found that the distribution was positively skewed and that a three parameter Weibull distribution, for example, provides a much closer fit as shown in Fig. 1.

Had the assumption of normality and the standard method of estimating the 5th percentile level been applied to this data a 5th percentile value of 732 p.s.i. (5000 kPa) would have been obtained. The normal and Weibull distributions are compared in Fig. 1. It does not appear reasonable to expect that realistic allowable stresses can be derived by a method which has such a great discrepancy in the statistical assumption. The 5th percentile level has been chosen as the characteristic value to be used for materials in limit states design.

Duration of Load

In tests recently carried out at the University of British Columbia (Madsen 1971, 1972*a*,*b*) in which the 'duration of load' concept was investigated it was found that the time–strength relationship was highly dependent upon the initial strength of the material. High strength material (almost clear) did lose strength approximately as predicted by the Madison duration of load concept, whereas weak material (containing knots) did not show a significant drop in strength with time. It was thus established that time to failure is not independent of initial strength as assumed in the present method of developing allowable stresses.

Since it is the weakest pieces of the population which determine the allowable stress it would appear that it is erroneous to apply the present duration of load factor. In most cases this has resulted in an error on the safe side. However, where the designer has used the permitted 100% increase for impact, it may have led to unsafe structures.

Moisture Content

As mentioned a factor for moisture content is also applied in deriving allowable stresses. In a test reported by Madsen (1972*a*, *b*) it was found that the strong portion of the material did show an increase in strength with decrease in moisture content. However, at the weak end of the population no such difference in strength could be detected. This is further evidence that the factors used in developing

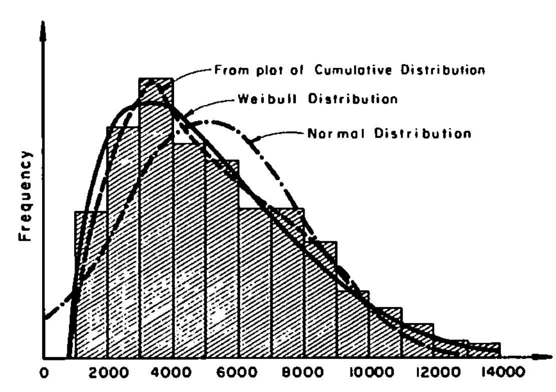

FIG. 1. Histogram and distributions for sample of two hundred and forty 2 × 6 joists (Weibull and normal).

allowable stresses are not independent variables as assumed.

Another illustration of the same observation is shown in Fig. 2. Two groups of 2 × 10 joist material were tested, one green (wet), the other after it had dried to 12% moisture content. Small clear specimens were cut from each of the joists and also tested in the wet or dry conditions respectively. The test results of the small clear specimens are shown at the bottom of Fig. 2.

The results are ranked from the smallest to the largest on the abscissa. The ordinate shows the failing stress. It can be observed that there is a pronounced difference in strength between the wet and dry testing conditions. In the top half of Fig. 2 the results are plotted in the same manner for the full size 2 × 10's. A strength difference does exist in the strong portion of the population of the full size 2 × 10 but this strength difference disappears at about the 10th percentile level.

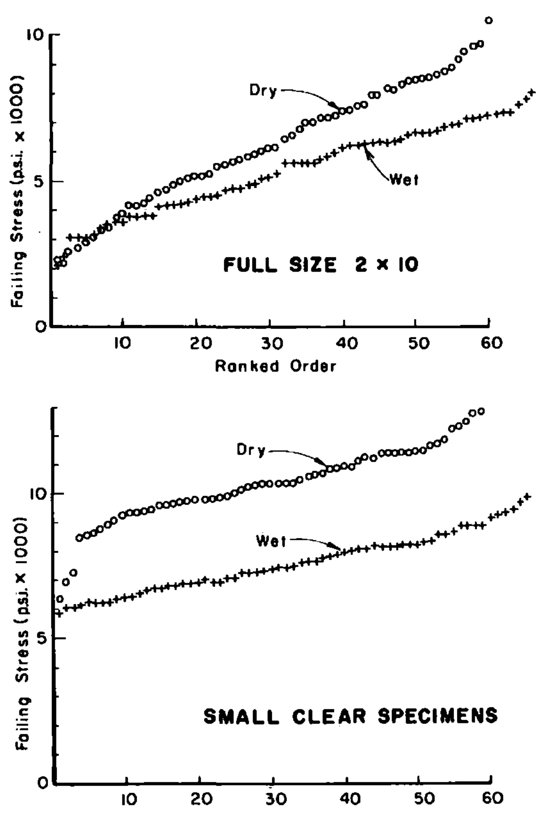

FIG. 2. The effect of moisture content upon strength.

This indicates that one cannot reliably transpose results from small clear specimens to full size commercial material.

Height Effect

The height effect observed from testing with clear material may very well be correct but it is questionable if the same reduction would take place with commercial material where knots are the cause of failure. Whether this effect is greater or smaller in commercial material is not easy to predict without testing but undoubtedly it could be tied to the grade of the material and hence height effect and grade effect could not be expected to be independent.

The observed height effect may very well be part of the size effect concept described by Barrett *et al.* 1975.

Grade Effect

As already pointed out, the grade factor has a pronounced effect upon F_{time} and F_{moisture} and may also be tied into F_{height}.

The present allowable stresses for joists in bending for #1 grade is 84% of the allowable stress for select structural grade, #2 grade is 68% and #3 grade is 40% of the allowable stress for select structural. However, in a test containing a total of eight hundred and fifty 2 × 6 Douglas Fir joists these ratios could not be confirmed. The results of the test are shown in Fig. 3. The normalized rank presentation is used.

It can be observed that the present grading rules do not create the purported differences between #1 grade and #2 grade. It would appear that #2 grade is stronger than #1 grade. The #2 and #3 grade are in approximately correct positions relative to the select structural grade.

The large spread in strength should also be noted. More than half of the select structural grade material has a strength of more than twice the strength at the 5th percentile level, indicating a poor performance from the present visual grading system.

Factor of Safety

The actual factor of safety at a specified percentile level is not well established since, as

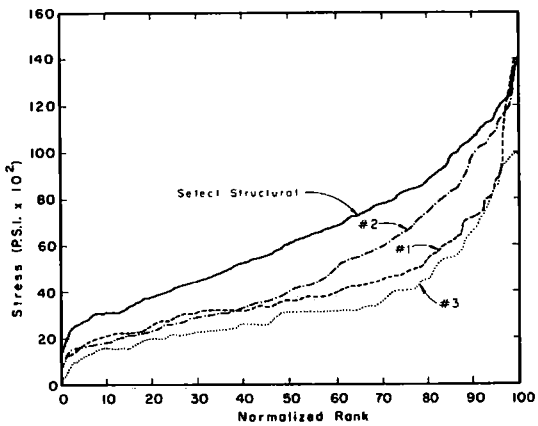

FIG. 3. Strength distributions of four commercial grades based upon eight hundred and fifty 2 × 6 Douglas Fir joists tested in bending.

mentioned, the factors (F_{time}, F_{moisture}, etc.) have been selected conservatively. The present method cannot be expected to result in consistent factors of safety and thus does not result in the optimum, economical, and safe use of wood.

It would be desirable to have a constant factor of safety and it should be about the same as for other materials. For example, a basic nominal safety factor on tensile yield of 1.67 is used for hot rolled steel, and 1.6 for aluminum and cold formed steel.

Alternative Method: In-grade Testing

General

In light of the above, it seems highly desirable to review the basis for our allowable stresses for wood or, looking to the future, the basis upon which we are to develop characteristic values to be used in conjunction with limit states design. It would appear that the small clear specimen approach has outlived its usefulness, since it does not manage to correctly reflect the strength of commercial material. A logical first step is to change from tests of small specimens to 'in-grade testing' (testing of the material as it is produced in the sawmill).

Such an approach may at first appear to be quite expensive but if one keeps in mind that we are mainly interested in the strength at the 5th percentile level, it is possible to use a proof loading technique and, thereby, reduce the amount of material which will be destroyed during the testing. A proof load which would break, say about 10% of the material, could be estimated or measured roughly through preliminary testing, and a large quantity of material could then be subjected to this load.

The breaking stress of any piece of material which fails before the full proof load has been applied will be recorded. Material which does not break will be returned to mill output, but the number of pieces that were stronger than the proof load stress will be recorded also. The failure stresses for the material which failed can be ranked and, since large samples can be tested inexpensively in this manner, the 5th percentile level can be obtained with the desired degree of accuracy.

Pilot Test

In order to obtain an assessment of the magnitude of work involved in this approach to deriving suitable characteristic values for wood, it was decided to carry out an experiment with 2 × 6 lumber in bending.

It is almost inherent in the method that the testing should be carried out in the sawmill rather than in the laboratory. The cost of bringing the material to the laboratory and a portion of it back to the mill again would be much higher than bringing a testing machine to the mill.

A small testing machine, as shown in Fig. 4, was therefore built. It consists of a steel I-beam, a hydraulic cylinder, a spreader bar, and a hydraulic pumping unit with appropriate valving. The rate of travel of the cylinder can be adjusted by a flow control valve and the maximum load can be preset on a pressure release valve.

The unit was made easily portable by cutting the beam into three sections and providing bolted connections. The whole unit could then fit into the trunk of an automobile (Fig. 5). The unit was calibrated on the laboratory equipment. Two technicians were sent to several sawmills and after having explained the purpose of the test, excellent cooperation was received from the mill personnel.

It was first established what species and grade mixtures were produced in the plant and the technicians would then request randomly selected packages of lumber to be brought to the testing machine. Each board in the package would be placed in the testing machine and the selected proof load applied. Initially, twice the

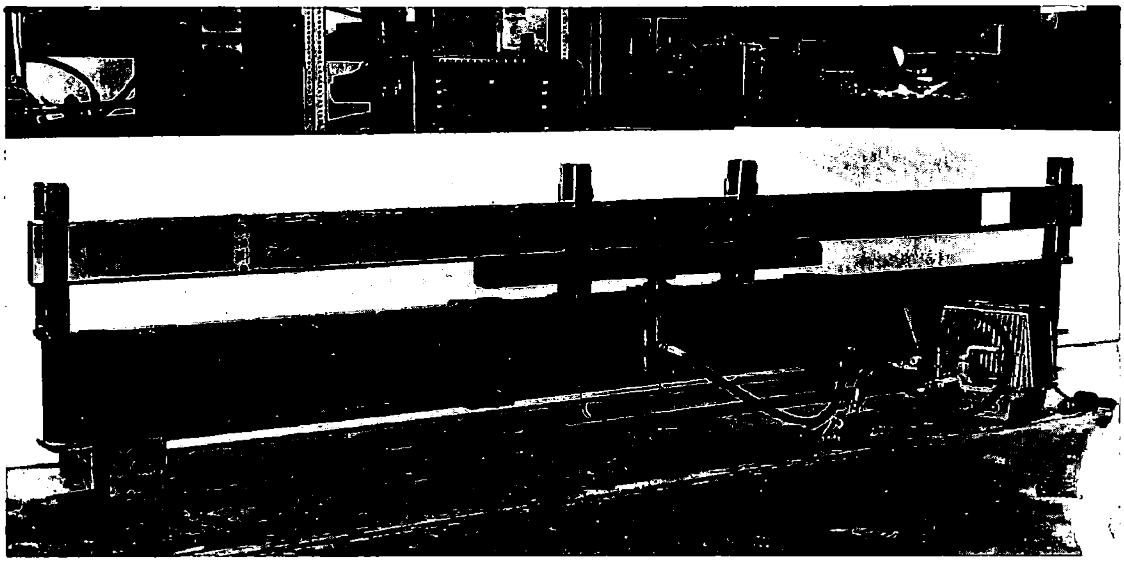

FIG. 4. Testing beam with hydraulic pumping unit.

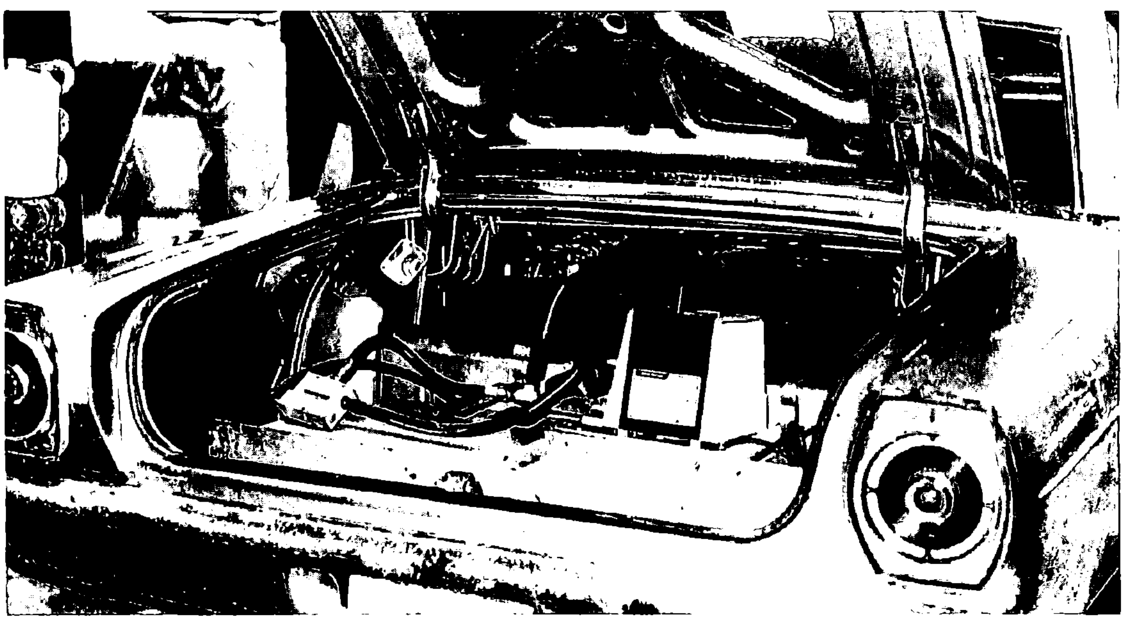

FIG. 5. Testing unit fitting into an automobile trunk.

present allowable stress was generated but it was found that only 3–5% of the boards would fail at that stress level and the proof load was subsequently increased to three times the design stress. The load was applied in about 5 s and held for an additional 15 s. If the board broke the failing load would be recorded as well as the moisture content and grade stamp on the board. A note of failure mode was also made. The boards which did not fail would be reformed into packages but the technicians would keep track of the grade marked on the board and also of the number of boards they found to be off grade. The two technicians

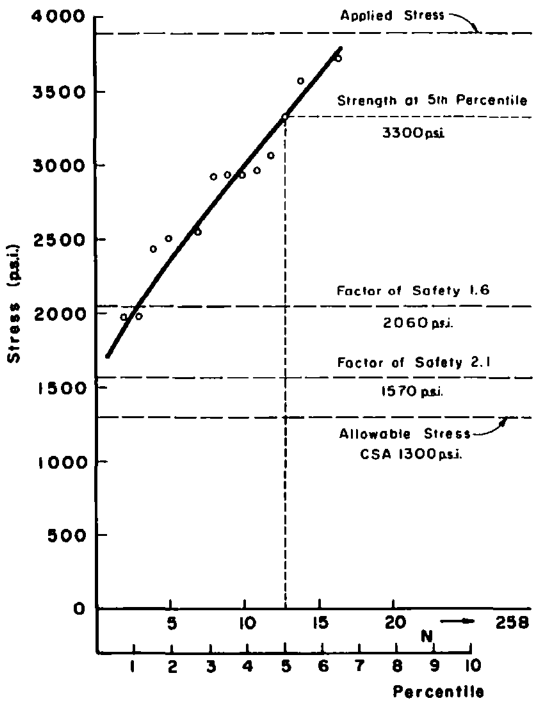

FIG. 6. Results of in-grade testing 258 Douglas Fir 2 × 6 joists of '2 and better' grade.

were able to test an average of 600 boards per day. An example of the test results is shown plotted in Fig. 6. The abscissa is the rank and the equivalent percentile is also shown. The ordinate represents the failure stress.

Test Results

One mill located on the coast and three mills in the interior of British Columbia were visited during this pilot test and the results are shown in Table 1. The results are, of course, not conclusive and can at best only show some trends.

One would expect variations in strength from location to location due to differences in growth conditions for the trees and many more mills would have to be investigated before conclusions could be established. A few of the mills should also be tested at different times to see by how much the strength would vary due to changes in log supply and grading practice.

It would appear from the table that the present allowable stresses do not result in a uniform factor of safety at the 5th percentile level. The 'Spruce–Pine–Fir' group seems underrated relative to the Douglas Fir. The #3 grade also seems underrated even though this grade should have been proof loaded at a higher stress level.

The absolute level of safety, or the characteristic values, cannot be derived from this kind of testing alone. The duration of load factor for commercial lumber is presently being investigated and before that test is completed it is not possible to establish the proper characteristic value. Similarly, the effect of moisture content should be further assessed for commercial material.

Other Tests for Lumber

The pilot investigation showed that it is practical to undertake in-grade testing of lumber in bending. However, other properties will also have to be included. Information on the modulus of elasticity was not collected in the pilot study but it would be very easy to obtain that data either as part of the proof loading or in a separate test. Since such a test need not be destructive, the whole sample could be measured and the full distribution of E-values obtained. This could be important information for design of structures where load sharing takes place.

In-grade testing for compression and tension values would require a different test setup but a portable apparatus could, no doubt, be designed to take care of both these properties. It may not be possible to transport such a heavy piece of equipment in a car; a light truck may have to be used.

Values for shear could possibly be obtained on the bending machine by use of a spreader bar which would place the load closer to the supports and, thus, create a loading more prone to failure in shear.

Testing of Glued-laminated Beams

The testing philosophy may have to be changed somewhat for glulam beams. The much greater cost of material would, no doubt, prohibit the use of as large samples as is envisaged for lumber. It will be necessary to develop a more refined statistical approach but it would be possible to use the proof loading approach even for testing of glulam beams in the plants. A few portable cylinders and an assortment of brackets would enable the technicians to make suitable test setups in which one glulam beam is tested against another.

TABLE 1. In-grade test results

SPECIES	GRADE	MILL	LOCATION	MOISTURE	SAMPLE SIZE	FAILURES	PROOF LOAD	ESTIMATED 5th PERCENT STRENGTH	CSA ALLOWABLE STRESS	APPARENT SAFETY FACTOR	GRADE COMPOSITION	PERCENT	CFF GRADE	PERCENT
DOUG. FIR	2 & Better	F	Coast	Wet	154	13	3900	2800	1300	2.16	178#1+76#2 +	70%#1	16	5.3%
DOUG. FIR	2 & Better	P	Int.	Dry	258	15	3900	3300	1300	2.54	172#1+86#2	67%#1	4	1.6%
FIR	2 & Better	L	Int.	Dry	320	17	3900	3700	1300	2.85	282#1+38#2	88%#1	28	10.0%
DOUG. FIR	#3	F	Coast	Green	250	6	1500	1750	750	2.30				
DOUG. FIR	#3	P	Int.	Dry	258	14	2250	1900	750	2.54				
HEM-FIR	2 & Better	F	Coast	Green	125	4	2850	3000	950	3.16	155#1+73#2 +	68%#1	16	7.0%
HEM FIR	#3	F	Coast	Green	256	0	1100	-	550	-				
SPRUCE,FP	2 & Better	P	Int.	Dry	256	1	2700	2700*	900	3.00+	172#1+84#2	67%#1	4	1.6%
SPRUCE,FP	2 & Better	L	Int.	Dry	320	11	2700	3100	900	3.44	166#1+154#2	52%#1	8	2.5%
SPRUCE,FP	#3	P	Int.	Dry	128	2	1800	1800*	600	3.60				
SPRUCE,FP	ECC.	P	Int.	Dry	143	4	1500	1800*	-	-				

* Estimate Too Low Due to Low Testing Level.

+ Extra Boards Tested at Twice Design: No Failures.

Obviously, the time required for each test would be much longer than for lumber but over a period of time very valuable information could be gathered. Fortunately, only a few stress grades of glulam are used.

Tension and compression tests for glulam could best be carried out in the laboratory since very heavy equipment is needed.

Other Testing

Characteristic values for connectors are already based upon full scale tests and any additional information required would best be obtained from laboratory testing. Plywood is now being tested in grade and should not present any additional problems.

Other Benefits

Using the proposed method it would be possible to collect data which could result in improvements of the grading rules. The personnel involved in the testing should be capable of grading according to the NLGA Standard Grading Rules of Canadian Lumbers. They should keep detailed records of what kind of defect appears to be the cause of failure. Through such records it may be possible to recommend improvements to the grading rules by identifying requirements which may now be unnecessarily restrictive. It may also be possible to identify defects which cause an unreasonable lowering of the strength for the grade. Such defects could possibly be prohibited for the grade under consideration.

Since the equipment involved in the testing (at least for bending) is rather inexpensive, it may be possible for the mills to obtain such equipment which would enable them to run periodic quality control checks. Alternatively, the grading supervisors should be equipped with portable testing units and they could run strength checks during their inspections. As it is today, very few graders have ever witnessed a bending test of a board and they would have very little knowledge of what kind of defect is liable to cause the most severe strength reductions.

Evaluation of the Proposed Method

The proposed method for obtaining characteristic values for wood has some very important advantages relative to the present method.

1. Large sample size can be obtained relatively easily, which will diminish the problem of statistical interpretation.
2. It deals with the end product and removes the uncertainties with regard to grade effect.
3. It deals with full size material and the size effect or height effect is included in the measurement.
4. The method can be used to interact with the grading rules and thus lead to improvements of them, which would result in better economical usage of our timber resource.
5. It would be possible to use the method to monitor the production and it could, thus, increase the reliability of the product.

The method does require that better knowledge and understanding of the duration of load phenomenon be obtained, but this would apply to the old method as well. It is also assumed that better information on the effect of moisture content should be obtained.

An apparent disadvantage is the cost involved in the testing. However, if one considers the possible savings which can be achieved through more economical use of timber, the cost of testing will be very small indeed.

Conclusions

1. In light of the upcoming change in the National Building Code of Canada to 'limit states design' it would appear that small clear specimens have outlived their usefulness as the basis for developing allowable stresses or characteristic values for wood properties.
2. In-grade testing using a proof loading approach seems to be a suitable alternate method for determining characteristic strength properties for wood to be used in conjunction with limit states design.
3. A more accurate time–strength relationship for commercial wood needs to be established and the effect of moisture content upon strength should also be clarified.
4. The proposed method affords direct opportunities for improving both the grading rules and the quality of the wood products.
5. Consideration should be given to establishing the strength properties in accordance with the commercial practice of selling mixed grades of lumber rather than for the grades by themselves.

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